



# Spitzer Enhanced Imaging Products Explanatory Supplement

Cryogenic Release v3.0  
December 2013



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## Chapter 1. Overview

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The Spitzer Science Center (SSC) and the Infrared Science Archive (IRSA) are providing the Spitzer Enhanced Imaging Products (SEIP), Cryogenic Release version 3.0. These are combined images (“Super Mosaics”) and tables (the most important being the “Source List”) for data from Spitzer’s cryogenic mission, including all four bands (3.6, 4.5, 5.8, and 8 microns) of the Infrared Array Camera (IRAC), and the 24 micron band of the Multiband Imaging Photometer for Spitzer (MIPS).

Spitzer users are no doubt familiar with the Spitzer Heritage Archive (SHA), the first stop for reduced data, where all data from both the cryogenic and warm mission are available, and mosaics are available for each imaging Astronomical Observation Request (AOR). IRSA also serves a number of imaging products and catalogs provided by Spitzer Guaranteed Time Observers and Legacy project teams at various times during the mission. The Spitzer Enhanced Imaging Products were made to widen the range of archival research by providing 1) combined data across multiple AORs, allowing extraction of faint sources, and 2) uniform processing using the final (best) calibration of the cryogenic imaging data. Table 1.1 summarizes the products available. Like most data served by IRSA, the SEIP images are searchable by position and the tables are searchable by position and column values. Position searches can be done through the web interfaces described below, or from within the SHA itself (Table 1.2).

The main table is a Source List (SL) of photometry for highly reliable compact sources. The SL offers an easily searchable database of approximately 42 million stars and galaxies. The priority is on reliability over depth. Using IRSA’s standard web services (see below), users can select and analyze sources of interest ranging from nearby cold stars to the most distant quasars. In addition to Spitzer photometry, the SL contains photometry for positional counterparts found in the AllWISE Release of the Wide-Field Infrared Survey Explorer (WISE) and in the Two Micron All Sky Survey (2MASS). See Table 1.3.

This Explanatory Supplement describes Cryogenic Release v3.0. This release includes data taken during commissioning and cryogenic operations, including calibration data. This document describes overall properties and how to get started quickly (Chapter 1), important caveats (Chapter 2), and the generation of the Super Mosaics (Chapter 3), Source List tables (Chapter 4), and other tables (Chapter 5). It does not cover details of the Spitzer instruments, or the WISE or 2MASS data, which are covered in the documents given below (Table 1.4). Changes from the previous version are provided in the Change Log (Chapter 6).

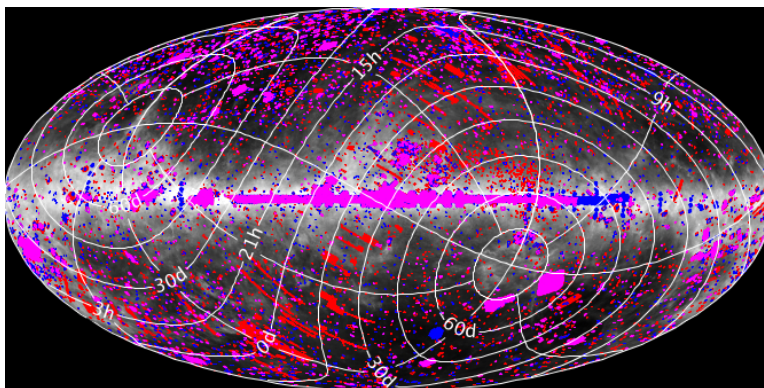


Figure 1.1 Aitoff projection of the coverage of the SEIP Cryogenic Release v3. IRAC observations are shown in blue, MIPS observations are shown in red, and magenta indicates both.

**Table 1.1 Summary of Spitzer Enhanced Imaging Products**

Spitzer Enhanced Product	Description
<i>*mosaic.fits</i>	Mean mosaic using Basic Calibrated Data frames (BCDs) across AORs where appropriate. Most users will measure photometry on this product. For IRAC observations taken in High Dynamic Range (HDR) mode, there will be two <i>*mosaic.fits</i> files per band, one with a "short" in the filename. In these cases, the Source List photometry is measured on the <i>*mosaic.fits</i> files, i.e. not the "short" ones.
<i>*unc.fits</i>	Mean combined uncertainty map which should be used for estimating errors.
<i>*cov.fits</i>	Mean coverage map indicating the number of images that went into each pixel, used to determine gain.
<i>*std.fits</i>	Measured standard deviation at each pixel.
<i>*median_mosaic.fits</i>	Median mosaic.
<i>*median_mosaic_unc.fits</i>	Median mosaic uncertainty.
<i>*softsatmask.fits</i>	Mask for soft saturation.
<i>*extmask.fits</i>	Mask for extended source region.
<i>*brightmask.fits</i>	Mask for nearby bright source.
Source List	Bandmerged list of photometry for high-reliability compact sources.
IRAC Coverage/Sensitivity Table	For each 4.6x4.6 arcsec region of the sky and each IRAC channel, this table provides the number of input BCD images, the uncertainty, the number of sources detected but rejected from the Source List, and flags indicating if the area is crowded or affected by bright or extended sources. This table is useful for determining why a source does not have an IRAC flux density in the Source List, and for obtaining photometry upper limits.

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MIPS Coverage/Sensitivity Table	Same as above, but for 9x9 arcsec regions of the sky and the MIPS 24 micron channel. This table is useful for determining why a source does not have a MIPS 24 micron flux density in the Source List, and for obtaining photometry upper limits.
Traceback Table	This table lists the AORs, Program IDs (PIDs), Super Mosaic IDs (SMIDs), and DCEs for each Super Mosaic.

**Table 1.2 Data Access**

Service	Notes
Spitzer Heritage Archive (SHA)	<ul style="list-style-type: none"> <li>• Web Interface: <a href="http://sha.ipac.caltech.edu/applications/Spitzer/SHA/">sha.ipac.caltech.edu/applications/Spitzer/SHA/</a></li> <li>• Primary Downloadable: Super Mosaics and Tables</li> <li>• Image Previews: One at a time</li> <li>• Catalog Overlays</li> <li>• XY Plots</li> <li>• SED Plots</li> <li>• Access to original observations</li> </ul>
Image Search (Atlas)	<ul style="list-style-type: none"> <li>• Web Interface: <a href="http://irsa.ipac.caltech.edu/data/SPITZER/Enhanced/Imaging/">irsa.ipac.caltech.edu/data/SPITZER/Enhanced/Imaging/</a></li> <li>• Program Interface Instructions: <a href="http://irsa.ipac.caltech.edu/applications/Atlas/AtlasProgramInterface.html">irsa.ipac.caltech.edu/applications/Atlas/AtlasProgramInterface.html</a></li> <li>• Primary Downloadable: Super Mosaics</li> <li>• Image Previews: One at a time or grid</li> <li>• Catalog Overlays</li> <li>• XY plots</li> </ul>
Cutout Server	<ul style="list-style-type: none"> <li>• Web Interface: <a href="http://irsa.ipac.caltech.edu/data/SPITZER/Enhanced/Imaging/index_cutouts.html">irsa.ipac.caltech.edu/data/SPITZER/Enhanced/Imaging/index_cutouts.html</a></li> <li>• Program Interface Instructions: <a href="http://irsa.ipac.caltech.edu/applications/Cutouts/docs/CutoutsProgramInterface.html">irsa.ipac.caltech.edu/applications/Cutouts/docs/CutoutsProgramInterface.html</a></li> <li>• Primary Downloadable: Super Mosaic Cutouts</li> </ul>
Catalog Search Tool (Gator)	<ul style="list-style-type: none"> <li>• Web Interface: <a href="http://irsa.ipac.caltech.edu/applications/Gator/">irsa.ipac.caltech.edu/applications/Gator/</a></li> <li>• Program Interface Instructions: <a href="http://irsa.ipac.caltech.edu/applications/Gator/GatorAid/irsa/Gator_api.html">irsa.ipac.caltech.edu/applications/Gator/GatorAid/irsa/Gator_api.html</a></li> <li>• Primary Downloadable: Tables</li> </ul>

**Table 1.3 Photometry included in the Source List**

Channel/Filter Name	Wavelength	Telescope/Instrument/Survey
J	1.25	2MASS
H	1.65	2MASS
Ks	2.17	2MASS
I1	3.6	Spitzer/IRAC
I2	4.5	Spitzer/IRAC
I3	5.8	Spitzer/IRAC

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I4	8.0	Spitzer/IRAC
W1	3.3	AllWISE
W2	4.7	AllWISE
W3	12	AllWISE
W4	23	AllWISE
M1	24	Spitzer/MIPS

**Table 1.4 Additional Documentation**

IRAC Instrument Handbook <a href="http://irsa.ipac.caltech.edu/data/SPITZER/docs/irac/iracinstrumenthandbook/">irsa.ipac.caltech.edu/data/SPITZER/docs/irac/iracinstrumenthandbook/</a>
MIPS Instrument Handbook <a href="http://irsa.ipac.caltech.edu/data/SPITZER/docs/mips/mipsinstrumenthandbook/">irsa.ipac.caltech.edu/data/SPITZER/docs/mips/mipsinstrumenthandbook/</a>
IRSA WISE page <a href="http://irsa.ipac.caltech.edu/Missions/wise.html">irsa.ipac.caltech.edu/Missions/wise.html</a>
IRSA 2MASS page <a href="http://irsa.ipac.caltech.edu/Missions/2mass.html">irsa.ipac.caltech.edu/Missions/2mass.html</a>

## 1.1 Quick Start Guide to using the Spitzer Enhanced Imaging Products

### 1.1.1 *Getting Started*

Let's assume you are using standalone tools to access the Spitzer Enhanced Imaging Products (that is, working outside the Spitzer Heritage Archive). You can get the Super Mosaics covering your position from the link in Table 1.2, Image Search. Scroll down the results page and download the images you are most interested in, generally \*mosaic.fits. You can get a Source List table in a given search radius with the link under Catalog Search. Scroll down and click Download Table.

The Source List will be a table in IPAC Table Format. This is a simple space-delimited table, with simple headers. If you use IDL, there are some IPAC table readers at [http://irsa.ipac.caltech.edu/tools/irsa\\_idl.html](http://irsa.ipac.caltech.edu/tools/irsa_idl.html). Table readers in Topcat and AstroPy can also read this format.

The columns are described in Chapter 4. The ones of most interest, other than ra and dec, are flux columns (in microJy) i\*\_f\_ap1, i\*\_df\_ap1, m1\_f\_psf, m1\_df\_psf. The \* indicates i1, i2, etc. for IRAC band 1, 2, etc. The "ap1" means an aperture flux in a 3.8



arcsec diameter aperture, with an aperture correction for a point-source already applied. The “psf” for “m1” (MIPS 24 microns) means a point-source fitted flux. The “df” means an uncertainty. Fluxes for a larger aperture for IRAC and an aperture flux for MIPS1 are also available, as well as bandfilled fluxes when something is detected at another wavelength, and 3sigma limits when appropriate, but these are the primary fluxes.

Along with the 2MASS flux columns, j (dj), h(dh), and k(dk) and WISE flux columns, wise1 (dwise1), etc., these should be enough to get you started with the Source List.

### 1.1.2 *Getting the Most Reliable Fluxes*

The SL contains only sources detected with a high signal-to-noise ratio in at least one band. The requirements for inclusion depend on whether the region is extragalactic or galactic. For extragalactic regions (*obstype* = 6), an object must be detected at the 10-sigma level in at least one channel (I1, I2, I3, I4, M1, J, H, K, W1, W2, W3, W4; see Table 1.3). For galactic regions (*obstype* = 3 or 4), an object must be detected at the 10-sigma level in at least two channels.

To retain only the most robust flux densities, apply the following cuts:

1. Make a SNR cut. Each source has 5 columns ending in “*fluxtype*”, four for each of the IRAC channels and one for MIPS-24. Flux densities with  $\text{SNR} \geq 3$  for IRAC and  $\geq 10$  for MIPS1 have *\*fluxtype*=1.
2. Eliminate IRAC flux densities that may be affected by a nearby saturated source or a nearby extended source. There are four “*fluxflag*” columns, one for each IRAC channel. Choose *\*fluxflag*=0.
3. Eliminate MIPS flux densities that may be affected by a nearby saturated source or a nearby extended source by choosing *m1\_brtfrac*<0.5 and *m1\_extfrac*<0.5.
4. Remove IRAC flux densities affected by soft saturation. There are four *\*softsatflag* columns, one for each IRAC channel. Choose *\*softsatflag*=0.
5. As long as you have filtered by *\*fluxtype* = 1 (item #1 above), then you can use the following rules. For IRAC, use the 3.8 arcsec diameter aperture flux densities and the associated uncertainties (columns *\*f\_ap1*). For MIPS, use the PSF flux density and the associated uncertainties (*m1\_f\_psf*).

### 1.1.3 *My object does not have an entry in the Source List!*

If you do not find the source(s) you expect, search for those positions in the IRAC and/or MIPS Coverage Tables. If the positions of interest are covered but your sources are not in the Source List, that indicates that your source was rejected from the Source List to ensure its overall

reliability. This can happen for a variety of reasons, which you can read about in Section 1.3 and Chapter 4. You may wish to measure your sources directly on the corresponding mosaics

## 1.2 Super Mosaics

The SEIP include Super Mosaics for regions of the sky where at least four exposures or Data Collection Events (DCEs) are present in a given band, and that meet one of the following requirements:

1. The region was observed with at least four exposures in any of the IRAC channels (3.6, 4.5, 5.8, and 8 microns) in high-dynamic range (HDR) or mapping mode. The coverage requirement was set to ensure robust outlier rejection.
2. The region was observed with MIPS channel 1 (24 micron) in scan or photometry mode. All MIPS 24 micron data have sufficient coverage for robust outlier removal.

Some data for a given region of the sky were *not* used to create mosaics. These include:

1. IRAC sub-array mode - This mode was designed to enable very short exposures for bright objects and/or a high temporal sampling. These are very specific experiments that can require a high degree of human intervention to obtain reliable results.
2. MIPS 70 or 160 micron data - These data often require processing with the Germanium Reprocessing Tools (GeRT) to remove artifacts created by bright objects. This processing requires a significant amount of manual intervention. Therefore, MIPS channels 2 and 3 are not included in the Spitzer Enhanced Imaging Products.
3. MIPS Spectral Energy Distribution (SED) mode
4. MIPS total power mode
5. IRS 16 or 22 micron data - IRS Peak-Up Imaging forms a very small subset of the total data in the archive.
6. Observations targeted at moving objects - Moving object mosaics require rejection of background sources and significant manual intervention to achieve acceptable results. Furthermore, moving object observations were specifically targeted at individual objects with little chance for serendipitous discovery.

## 1.3 Source List

The Source List (SL) provides a list of highly reliable sources extracted from the Spitzer imaging archive. The SL processing was designed to prioritize reliability over completeness or areal

coverage. In order to make the Source list reliable, many sources were rejected. As a result, it is not complete at any flux density. At bright flux densities, nearby galaxies may be rejected for being too extended, or for being too close to a neighboring galaxy. At faint flux densities, sources will be missing because they do not meet the signal-to-noise ratio cut or did not make the cuts in place for a compact true source. Although the Source List is useful for many science projects, users who require high levels of completeness are encouraged to use caution. If you are interested in a source that does not appear in the Source List, you should consider measuring the photometry on the Super Mosaics yourself.

Reliability is defined as:

1. There must be fewer than 0.01% spurious sources for extragalactic cases (*obstype* = 5 or 6), 0.05% for galactic cases (*obstype* = 3 or 4) without structured extended background, and 0.2% for galactic cases (*obstype* = 3 or 4) with structured extended background. (For a description of *obstype*, see Section 3.1.) Evidence for structured extended background is taken from the extended source masks (*\*extmask*) in the relevant Coverage Table (see Section 5.1), which is reflected in the *\*extfrac* flags in the Source List (see Table 4.8).
2. Photometry should be good to 10% for high signal-to-noise, isolated point sources.

In order to meet these criteria, some sources that were detected in the Super Mosaics were rejected from the SL according to the following rules:

1. If a source is in a region flagged as extended, flagged as bright, or classified as galactic (*smid* starting in 3,4), at least two ten-sigma IRAC detections are required for the source to be included in the Source List. All other types of sources must be detected at the ten-sigma level in at least one IRAC band. This eliminates spurious sources that arise from the detection of noise peaks and knots of extended emission from galaxies or the interstellar medium.
2. To appear in the Source List, an object must have a mean coverage over its aperture of at least three for IRAC and four for MIPS. A threshold of three rather than four was adopted for the catalog because outlier rejection and drizzling often reduce the mean coverage to less than four in the coverage tables when there are in fact four exposures present. Note that at the edge of the mosaics the coverage is often much lower than in the center.
3. Sources that were too highly peaked were rejected because they are likely to be cosmic rays. Highly peaked sources were identified by comparing the peak magnitude and the 3.8 arcsec diameter aperture magnitude. Only sources meeting Peak Magnitude – Aperture Magnitude > 2.7 were included in the Source List.
4. Sources that have highly asymmetric spatial profiles are rejected since these are often multiple objects blended together. The Source List requires Peak Position – Centroid < 0.9 arcsec.

5. The following flags were applied if a source was detected at  $>10$  sigma in only one IRAC band or if the source was in a bright or extended source mask:
  - Sources with  $\text{FWHM} < 1.2$  arcsec were rejected because they are likely to be cosmic rays or other artifacts, and therefore spurious.
  - Sources with  $\text{FWHM} > 3.6$  arcsec were rejected because they are too large for accurate photometry to be measured and are likely artifacts.
  - Sources with spatial profiles that are very broad are rejected because they are likely artifacts. The Source List requires  $\text{Peak\_Magnitude} - \text{Aperture Magnitude} < 3.2$ , where magnitude is measured in a 3.8 arcsec diameter aperture.
6. Moving objects were rejected by performing source detection on the median images.

## Chapter 2. Cautionary Notes

The Spitzer Enhanced Imaging Products were created from a large, inhomogeneous set of data, with the mandate that the number of spurious and poorly measured sources be minimized. This section summarizes some limitations due to these requirements.

### 2.1 Source List

#### 2.1.1 *The Source list is incomplete.*

Below are some of the reasons a source may not appear in the SL.

**Table 2.1 Source types missing from Source List**

Missing Sources Types	Explanation
Very Extended Sources	Photometry for sources that appear very extended in a band is not included in the Source List. For example, Arp 220 is extended in IRAC channel 1. Therefore, $il\_fluxtype = 4$ (extended source) and all the $il^*$ photometric columns are listed as “null”. Users interested in photometry for extended sources may be able to use the Super Mosaics to derive their own photometry.
Non Point-Like Sources	A true source may not appear in the SL if it did not make any of the morphological cuts in Section 1.3.
Sources Near Bright Objects	This is fairly typical for automated source detection algorithms – it is difficult to separate true companions from noise peaks in the PSF.
Insufficient Coverage	If a large swath of a Super Mosaic lacks detections, this is the most likely reason.
Sources along Column Pulldown artifacts	Column pulldown is an artifact that occurs in IRAC images. The IRAC cryogenic pipeline identifies and corrects this artifact. To preserve information about the presence of the original artifact, the pipeline flags the entire column, and sets the associated CBCD uncertainties very high. The Source List pipeline interprets these flags as fatal, and does not report any sources along these columns. Some of these

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	sources may be real, but the masking is conservative to avoid reporting spurious sources.
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### 2.1.2 *Spurious Sources*

Although spurious sources have been minimized as much as possible, some do appear in the Source List, as summarized in Table 2.2.

**Table 2.2 Types of spurious sources in the Source List**

<b>Spurious Source Type</b>	<b>Explanation</b>
Latent images in MIPS channel 1	Bright latents occur in the MIPS1 array after a bright object hit. These are usually masked, but some are mistakenly listed as true sources.
Bright object artifact peaks	Bright objects can lead to striping on the array, and a peak in a stripe may look like a true source.
Residuals of moving objects	Typically seen in MIPS 1 near the ecliptic plane. An example is shown below.

### 2.1.3 *The Source List may not agree with Legacy Catalogs*

The Source List differs from Legacy Catalogs in a number of ways. While each case is different, a few general differences are summarized in Table 2.3.

**Table 2.3 Comparison of Source List and Legacy Catalogs**

<b>Characteristic</b>	<b>Source List</b>	<b>Legacy Catalog</b>
Input Images	The Source List is derived from Super Mosaics that stack all of the Cryogenic Imaging data taken at a given spot on the sky.	Legacy catalogs are typically derived from imaging data taken as part of a single observing program.
Calibration	The Source List uses the final photometric calibration derived by the Spitzer Science Center.	Legacy catalogs employ the calibrations available at the time of delivery.
Photometric Analysis	The Source List was created using consistent analysis of	Each Legacy team employed their own analysis techniques

	imaging data.	in creating the delivered catalogs. As a result, these vary from catalog to catalog.
Completeness	The Source list was designed to be reliable (with few spurious sources and accurate photometry) rather than complete.	Legacy catalog were created under a variety of requirements which are typically more lax on reliability and more stringent on completeness.

#### 2.1.4 Saturated sources

Fully saturated sources in IRAC data have been rejected from the Source List. However, IRAC data become non-linear at high count levels, before full saturation. While the IRAC BCD pipeline attempts to account for this non-linearity, the correction is imperfect. Objects in the Source List that are potentially non-linear are flagged with the *softsatflag*. The minimum exposure time in a mosaic is used to estimate the DN in the original images, and hence the non-linearity level. However, the process of calibration and background matching causes the conversion from MJy/sr in the mosaics to DN in the raw images to vary as a function of position, so the estimate will typically be an under-estimate. To account for this uncertainty, the soft saturation level is empirically set at 15,000 D/N based on inspecting the 2MASS K - IRAC flux densities for stars in the SWIRE and SMOG data. The value recorded in the *softsatflag* is the number of pixels in a 3.8 arcsec diameter aperture that are potentially non-linear.

Extremely saturated MIPS sources are rejected from the MIPS single-band Source List. Sources that are mildly saturated will be included in the MIPS single-band Source List. The PRF-fit photometry for these mildly saturated sources accounts for saturated pixels. Aperture flux densities are not corrected for saturated pixels.

#### 2.1.5 Bandmerged multiwavelength catalogs are associations, not identified counterparts

Each row in the Spitzer Source List contains columns with IRAC channels 1-4, MIPS channel 1, 2MASS *JHK*, and AllWISE channels 1-4. The multiwavelength information was compiled by using a simple positional search. See Section 4.3 for details. There is no guarantee that the long wavelength information is physically associated with the short wavelength data.

#### 2.1.6 Incorrect bandmerging in close pairs

When there are two IRAC sources very close to one another, sometimes only one of the pair is bright enough to make it into the Source List. It is possible that the spectral energy distribution of the second object in the pair rises to higher flux densities at longer wavelengths and gives rise to

the MIPS 24 micron source. In these cases, the 24 micron source will be associated with the bright (wrong) IRAC source.

**2.1.7 *Photometry near bright and/or extended sources may be unreliable: check the flags.***

The pixels within a source may be contaminated by flux from a nearby bright and/or extended source. This contamination may lead to an overestimate in the flux reported for a source. Users can identify such problem sources by examining the *\*fluxflag* column in the Source List.

**Table 2.4 Definition of \*FluxFlag**

<b>*FluxFlag</b>	<b>Description</b>
0	normal region
1	extended region
2	bright region OR bright and extended region

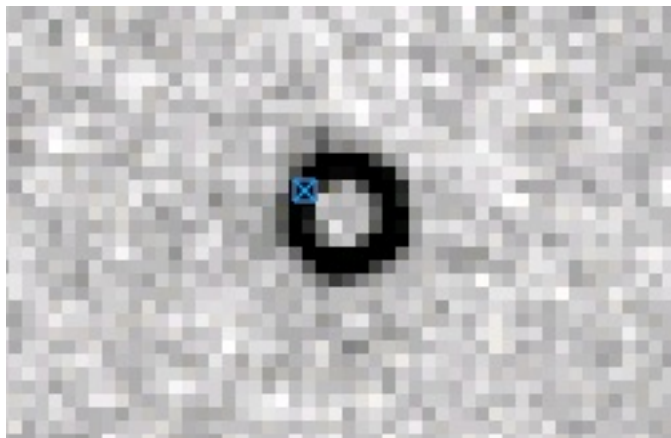
**2.1.8 *Structured backgrounds***

In regions with complex backgrounds, errors may be underestimated in the Source List. Structured background is not well-subtracted by the default median subtraction, and this is not accounted for in the uncertainty estimates.

**2.1.9 *MIPS 24 micron asteroid doughnut hole edges can be included in the Source List***

Incomplete cancellation of an asteroid in the mosaic step can leave a “doughnut” hole in the Mosaic, most likely at MIPS 24 microns near the ecliptic plane. Bumps or edges may be mistaken for a true source.

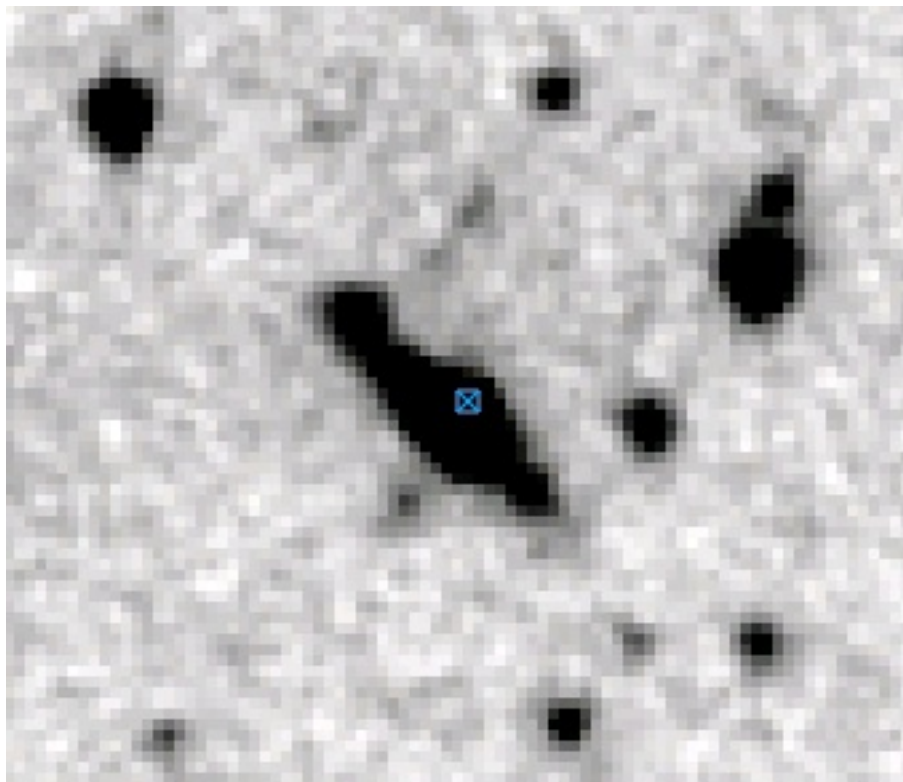




**Figure 2.1** Cutout of M1 mosaic of 40009211-149, centered at roughly  $ra=63.94314$  deg,  $dec = 23.762485$  deg. The blue box with a cross through it marks the position of an object in the Source List.

#### ***2.1.10 Source List positions off bright IRAC source peaks***

The reported  $ra$  and  $dec$  are from the shortest-wavelength 10-sigma Spitzer detection. This position can sometimes correspond to a MIPS 24 micron band, even if there is a bright source in IRAC. If the IRAC source is extended, its directly-measured photometry will be rejected from the Source List. Instead, a bandfill flux density will be provided. The position chosen for the bandfill will be the MIPS 24 micron position. Because the 24 micron channel has significantly lower resolution than the IRAC channels, the 24 micron position can appear significantly discrepant from the peak of the bright, extended IRAC source.



**Figure 2.2** Example of a bright, extended IRAC channel 1 source near  $ra = 22.15826$  deg,  $dec = 16.77308$  deg. Because this object is extended, it has  $i1\_fluxtype=4$  (the source is real, but its flux density cannot be measured accurately, so it is not reported);  $i2\_fluxtype=0$  (no IRAC channel 2 data available);  $i3\_fluxtype=2$  (there was not a ten-sigma source detected in channel 3, but a  $>3$ -sigma bandfill flux density was measured at  $ra,dec$ );  $i4\_fluxtype=0$  (no IRAC channel 4 data available); and  $m1\_fluxtype=1$  (a ten-sigma source was detected in MIPS channel 1). For this source,  $ra$  and  $dec$  come from MIPS channel 1, which does not line up exactly with the bright, extended IRAC channel 1 source.

## 2.2 Super Mosaics

### 2.2.1 *Super Mosaics differ from Legacy images*

The Spitzer Enhanced Imaging Mosaics differ from the mosaics delivered by Legacy Teams for the same fields, for a variety of reasons summarized in Figure 2.3.

**Figure 2.3** Differences between Super Mosaics and Legacy Mosaics

<b>Characteristic</b>	<b>Super Mosaics</b>	<b>Legacy Mosaics</b>
Input DCEs	The Super Mosaics were constructed using all of the DCEs available for a given position. As a result, some Super Mosaics are deeper than their Legacy counterparts.	The Legacy Teams typically used only the data associated with their own programs.
BCD pipeline version	The Super Mosaics were constructed using the final pipeline versions for the IRAC and MIPS BCD pipelines.	Legacy Teams used a variety of pipeline versions, depending on the time of delivery.
Artifact Mitigation	The artifact mitigation used to create the Super Mosaics is described in Section 3.4.	The artifact mitigation varies between Legacy programs.

### ***2.2.2 Bright source masks may suffer from proper motion effects***

The AllWISE catalog is used to identify bright sources for constructing bright source masks for the Source List. Since there can be a time differential between the WISE survey and data in the Source List, unknown or uncertain proper motions for WISE stars can cause bright source masks to be placed incorrectly.

### ***2.2.3 Variable sources are averaged out***

All the AORs available for a given part of the sky, even if they were observed years apart, are used to create the Super Mosaics. This procedure has the advantage of achieving the greatest depth possible. It has the disadvantage that the flux from variable sources is averaged out. Those interested in variable sources will need to use the Spitzer Heritage Archive to get the original BCD's.

### ***2.2.4 IRAC HDR Mode***

IRAC observed a subset of cryogenic data in High Dynamic Range (HDR) mode. In this mode, a short and a long exposure were taken at each position. The SEIP include two mosaics at each position that was observed in HDR mode. However, the short exposures are not used in the generation of the Source List.

### ***2.2.5 Latent images in MIPS 24 micron data***

Latent images fall in predictable positions based on the locations of bright objects in previous exposures. As a result, they can be masked by finding bright objects and then masking that array

position in subsequent exposures. However, latents are not corrected if they come from previous AORs.

## Chapter 3. Super Mosaics

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The Enhanced Imaging Products include Super Mosaics, which combine all BCDs for a given region. If the combined image is larger than two square degrees, multiple mosaics are created.

### 3.1 Observation Types

To ensure appropriate mosaicing parameters (namelists) were used for each mosaic and disparate AORs were not combined into a single mosaic, AORs were divided into five different Observation Types. The Observation Type for a given source is recorded in the *obstype* column of the Source List, as defined in Table 3.1:

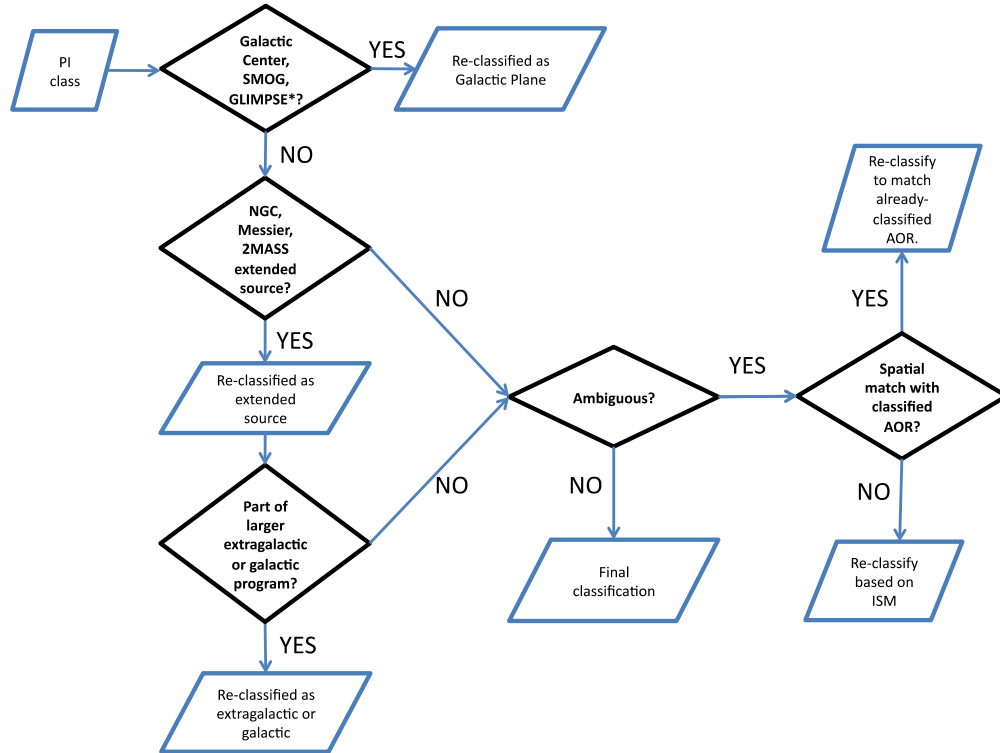
**Table 3.1 Encoding of *obstype* column in Source List.**

<b>obstype column in SL</b>	<b>Observation Type</b>
2	Zodiacal Background Observation
3	Galactic Plane Observation
4	Galactic Object Observation
5	Extended Object
6	Extragalactic Observation
7	Extremely deep extragalactic observations embedded in shallow fields

An overview of how *obstype* was assigned is provided in Figure 3.1. The proposal science class input by the Principal Investigator (PI) for each program was used as the primary way to identify AORs. However, a significant number of AORs were re-classified based on other criteria. Objects with NGC numbers, Messier numbers, or in the 2MASS extended source catalog were re-classified as extended sources. However, extended sources were re-classified as galactic or extragalactic if the extended sources corresponded to an existing galactic observation or were part of a larger extragalactic program that happened to overlap the extended source (e.g. MIPS GAL and SWIRE). Calibration data and ambiguously classified data (e.g. gamma ray burst observations in a Galactic Plane field and observations of nearby stars at high galactic latitude) were initially assigned an unknown flag. If these observations spatially matched a classified AOR they were assigned that science class. Otherwise, they were assigned a class based on the mean ISM emission in the AOR. “Stellar population” observations targeting nearby galaxies or globular clusters were re-classified as extended source observations. All MIPS GAL, Galactic Center, SMOG, GLIMPSE, GLIMPSE2, and GLIMPSE-3D observations were classified as Galactic Plane observations rather than galactic observations to make the process of matching and dividing up the Super Mosaics into Regions simpler and more practical.

Zodiacal light measurements were separated from all other classes of observation because they typically consist of very long scans with MIPS that intersect a wide variety of other programs and hence would create a heterogeneous set of mosaics. Flat field calibration frames were also

classified as zodiacal light measurements because they typically contain much higher background levels than science observations.



**Figure 3.1** Flowchart showing how obstype is assigned for a given AOR.

## 3.2 Super Mosaic Naming Scheme

Contiguous AORs of a given Observation Type were grouped into one Super Mosaic labeled with a Super-Mosaic-ID (*smid*) number. The first digit of the *smid* indicates the Observation Type according to scheme laid out in Section 3.1, and the *smids* of some well-known data sets are provided in Table 3.2.

**Table 3.2** *smids* of some well-known data sets.

<b>smid</b>	<b>Data set</b>
60095761	SWIRE Lockman Hole
60095871	SpUDS
60095881	GOODS-S
70101880	Groth Strip
70101860	GOODS-N
60087831	SDWFS/MAGES

60095931	SCOSMOS
60080780	SSA22
60095751	Spitzer X-FLS (in SDSS)
40009211	Taurus
30002711	SMOG
40017201	Chamaeleon II
40011571	Lupus I
40020261	Perseus
40015561	Ophiuchus
40027151	Serpens

### 3.3 Regions

If a given Super Mosaic is larger than 0.25 square degrees, it is broken up into 300x300 arcminute Regions. Each Region overlaps its neighboring Regions by 2.5 arcminutes (approximately 50% of an IRAC frame) on each side. This overlap ensures that all frames covering a given Region are included in the outlier rejection procedure. It also allows objects smaller than 2.5 arcminutes to be analyzed on a single mosaic. Super Mosaics that are divided into multiple Regions have SMIDs that end in 1, while Super Mosaics that are smaller than 0.25 square degrees have SMIDs that end in 0.

Each Region is labeled by a *regid*. The *regid* always begins with the *smid* followed by a “-”, followed by a Tile Number. For example, a *regid* of 40002981-108 has an *smid* of 40002981 and a Tile Number of 108. Two sets of mosaics are created per position for IRAC data taken in High Dynamic Range (HDR) mode. The short frames are assigned a *regid* with “-short” suffix. An example is 40002981-108-short.

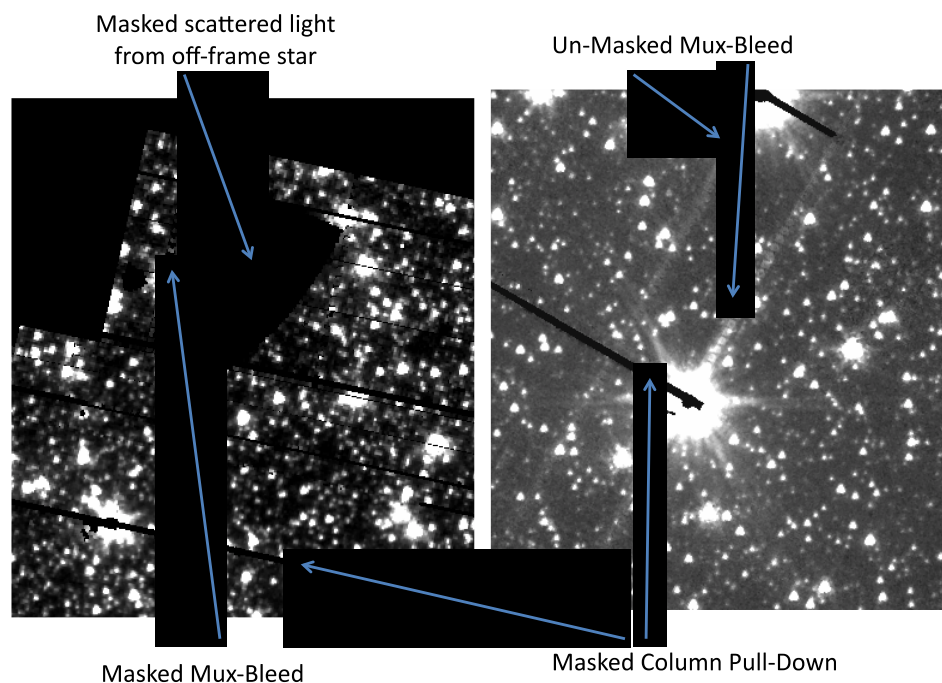
### 3.4 Image Artifact Mitigation

#### 3.4.1 IRAC

IRAC BCD data contain several artifacts, including mux-bleed, mux-stripe, column droop, and bright star ghosts, all of which are described in detail in the [IRAC Instrument Handbook](#). The IRAC pipeline produces cBCD images, which are an attempt to mitigate these artifacts. The SEIP Super Mosaics are built from cBCD data.

Before generating mosaics, problematic cBCDs were removed. The first frame of all IRAC AORs has decreased sensitivity and was not included in the mosaics. The second frame of some IRAC observations has a short exposure time relative to the majority of exposures and was removed in these cases. Finally, observations taken in High-Dynamic-Range (HDR) mode were split into short and long exposure mosaics.

However, since mux-bleed is not completely corrected in the cBCDs, sources found in regions where mux-bleed is likely affecting photometry were rejected from the Source List. See Figure 3.2.



**Figure 3.2 Example Region Mosaic created from IRAC cBCD data.**

### 3.4.2 MIPS

MIPS data suffers from various artifacts, including jailbars and latent images. See the [MIPS Instrument Handbook](#) for details, and Figure 3.3 and 3.4 for examples. The MIPS BCD images were run through a new MIPS Corrector module to mask latent images and correct the flat field. In the following, we refer to the output of this MIPS Corrector module as MIPS CBCDs.

The first frame of all MIPS AORs has decreased sensitivity and was not included in the mosaics. In addition, the second and last frames of MIPS fast scan observations are also problematic and were removed.

The MIPS instrument relies on a movable mirror to dither observations in photometry mode and to track in scanning mode. The position of this mirror cannot be precisely measured or repeated, creating observation-to-observation differences in the instrument flat field. This is particularly problematic for 24 micron photometry mode data taken in parallel to 70 or 160 micron observations since the scan mirror position is poorly understood in this mode. These flat fielding errors typically create significant gradients across parallel mode observations and a grid-like artifact in primary mode observations. Furthermore, the response of any individual pixel suffers



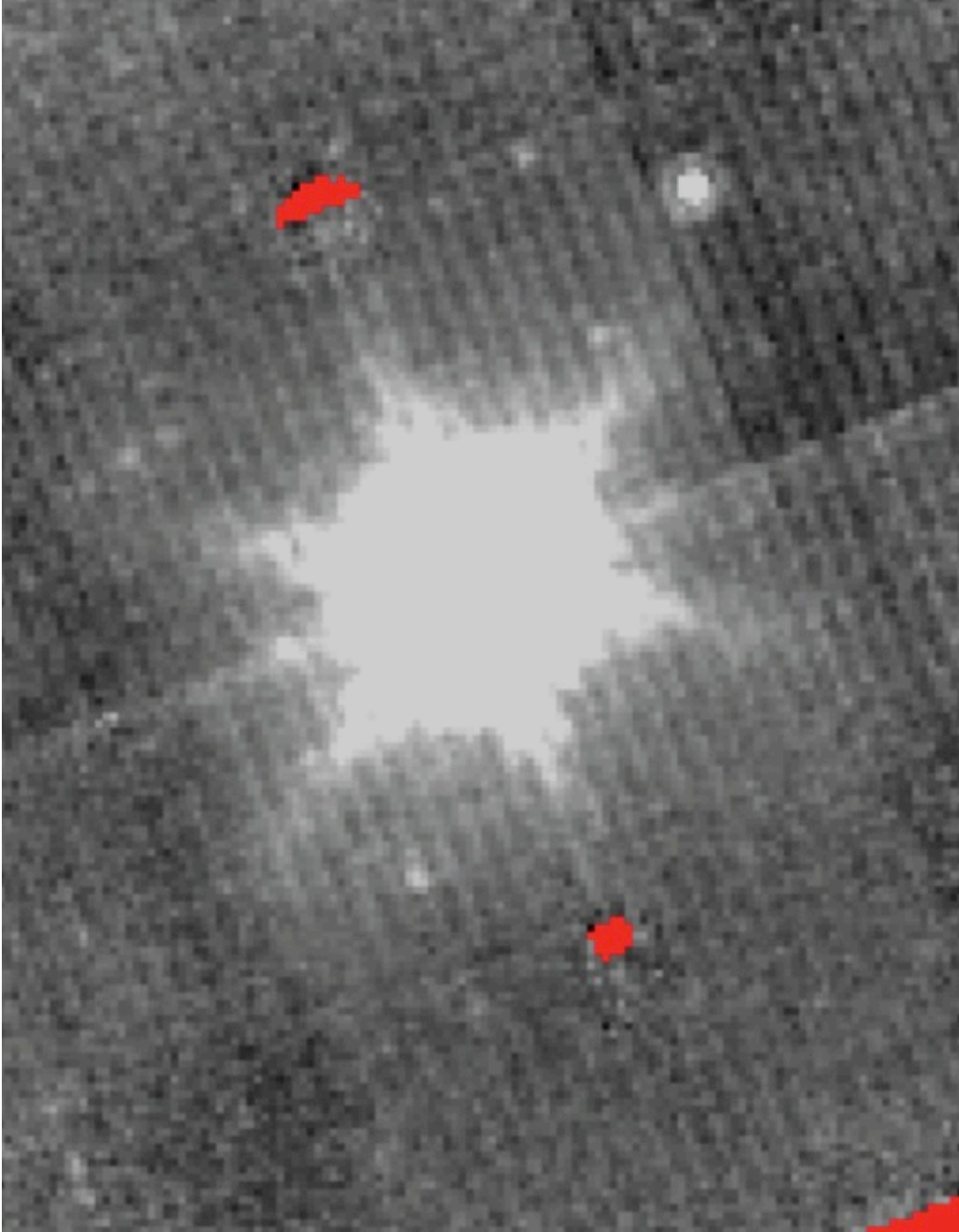
hysteresis effects that can change its response from observation to observation and create residual images of bright objects that can persist for a significant amount of time.

The flat field artifacts can be corrected by creating a median flat using the background light in science observations. However, this will fail for photometry mode observations that are not sufficiently dithered if they contain a significantly extended object or a significant amount of structure from galactic cirrus. To create a median flat, objects are first found and masked using the MOPEX package, then the dithered or scanned observations are combined to create a median flat. A separate median flat is created for each Field of View (FOV) in photometry mode or each scan leg in scan mode. These median flats are then divided into the data images.

Latent images fall in predictable positions based on the locations of bright objects in previous exposures. As a result, they can be masked by finding bright objects and then masking that array position in subsequent exposures. However, latents are not corrected if they come from previous AORs.



**Figure 3.3** Example of MIPS artifacts. Note latent images. A [MOPEX](#) corrector module masks these.



**Figure 3.4 Example of MIPS artifact – jailbarring and bright source stripe. The red indicates masked latents.**

### 3.5 Mosaicking Parameters

All mosaics were generated using the [Spitzer MOsaicker and Point source EXtractor \(MOPEX\) package](#). The MOPEX Overlap pipeline subtracts the estimated background from Zodiacal light from each CBCD and then matches the background level in all frames with an additive correction. Starting with the background matched BCDs, the MOPEX Mosaic pipeline performs outlier rejection to remove cosmic rays, moving objects, and other artifacts, then re-samples the images onto a common reference frame and combines the images to produce a weighted mean and median mosaic along with associated coverage, uncertainty, and standard-deviation maps.

The parameters for both the Overlap and Mosaic pipelines are sensitive to extended emission from the interstellar medium and to the number of exposures per pointing (coverage). In general, IRAC coverages of less than 10, 10 to 50, and greater than 50 frames require different outlier rejection and interpolation kernel settings. For MIPS the coverage does not make a significant difference in the choice of outlier rejection or interpolation kernel settings. For both IRAC and MIPS galactic observations with structured backgrounds required different outlier rejection settings than extragalactic fields with uniform backgrounds.

Due to the large volume and heterogeneous nature of the data included in the Spitzer Enhanced Imaging Products, the reduction parameters were limited to six cases rather than an optimizing each data set individually. The six cases are:

1. Extragalactic Shallow (coverage < 10)
2. Extragalactic Medium Coverage (10 < coverage < 50)
3. Extragalactic Deep Coverage (coverage > 50)
4. Galactic Shallow Coverage (coverage < 10)
5. Galactic Medium Coverage (10 < coverage < 50)
6. Galactic Deep Coverage (coverage > 50)

Table 3.3 and Table 3.4 summarize the key reduction parameters for each case listed above.

Module	Shallow	Medium	Deep	Galactic
Overlap	X	X	X	X
Dual Outlier	X			X
Box Outlier	X	X	X	X
Temporal Outlier	X	X	X	X
Pixel Size	0.6"	0.6"	0.6"	0.6"
Interpolation	Linear	Drizzle=0.75	Drizzle=0.25	Linear
Refine Outlier	Yes	No	No	Yes
Temporal Outlier Threshold	4	3	3	6
IRAC Source Detection/ Extraction	SExtractor	SExtractor	SExtractor	SExtractor

**Table 3.3 Summary of MOPEX module setups used for creating IRAC mosaics. Drizzle is preferred because of the gain in noise properties and PRF.**

Module	Extra-Galactic	Galactic
Flat Field	X	X
Overlap	X	X
Dual Outlier	X	X
Box Outlier	X	X
Temporal Outlier	X	X
Pixel Size	2.45"	2.45"
Interpolation	Linear	Linear
Refine Outlier	No	Yes
Temporal Outlier Threshold	3	6
IRAC Source Detection/ Extraction	APEX	APEX

**Table 3.4 Summary of MOPEX module setups used for creating MIPS 24 micron mosaics.**

## 3.6 Mosaic Products

There are four main FITS files associated with each Region. The type of file is denoted by the suffix before “.fits” in the file name. The file types are described in Table 3.5. The calibration offset required for S18.18 IRAC data has been applied to all Spitzer Enhanced Imaging mosaics.

**Table 3.5 Types of Mosaics**

<b>Suffix</b>	<b>Description</b>
<i>mosaic</i>	mean mosaic which should be used for measuring photometry
<i>unc</i>	mean combined uncertainty map which should be used for estimating errors
<i>cov</i>	mean coverage map indicating the number of images that went into each pixel, used to determine gain
<i>std</i>	measured standard deviation at each pixel

In addition to the FITS images listed above, a list of all DCEs used in a mosaic is provided.

### 3.6.1 Uncertainty Maps

The uncertainty maps represent the best guess at the combined background and Poisson noise at the given pixel position based on the basic calibrated data (BCD) products produced by the Spitzer calibration pipeline. They were produced by the MOPEX mosaic pipeline and include corrections due to interpolation and outlier rejection in addition to the noise expressed in the BCD pipeline. The mean uncertainty mosaics reflect the noise in the final mosaics, and the standard deviation maps reflect the measured standard deviation of the input data pixels that were included in the mean mosaic at this point.

### 3.6.2 Coverage Maps

The coverage maps represent the number of input DCE images that were included at each pixel of the output image. If a pixel was rejected due to outlier rejection or masking, it is not included in this count. If Drizzle interpolation was used, input pixels are mapped to less than a full input pixel (determined by pixfrac), resulting in reduced coverage. Even if mages with different exposure times were combined in one mosaic, the coverage is still one per image.


## 3.7 Mosaic Access

The Mosaic Products described above can be accessed in two ways: Atlas and the Cutout Service. Atlas provides full access to the entire Super Mosaics and DCE Lists. The Cutout Service provides access to small portions of a given Super Mosaic. Both services are described in more detail in the following sections.

### 3.7.1 Mosaic Access through Atlas

[Atlas](#) provides access to full Super Mosaics and associated FITS files. You can access Atlas to search for and download mosaic products using the form at the top of the page at <http://irsa.ipac.caltech.edu/data/SPITZER/Enhanced/Imaging/>

It looks like this:

<b>Target Selection</b>	<input checked="" type="radio"/>	<b>Single Object</b> (Name or Coords)	<input type="text"/>
	<input type="radio"/>	<b>Table Upload</b> (Multi Object) 	<input type="text"/> <input type="button" value="Browse..."/>
<b>Size (deg):</b> [maximum 0.6]	<input type="text" value="0.3"/>	<input type="checkbox"/>	<b>Images must cover coordinate</b>
		<input type="button" value="Submit"/>	<input type="button" value="Reset"/>

**Coordinate Examples:** Arp 220 |  
 216.79512 34.88702 eq | 58.148111 68.68589 ga |  
 199.83998 45.73146 ecl

**Default:** Equatorial J2000

**Figure 3.5 Atlas interface to Super Mosaics.**

After searching for a Super Mosaic, you have the option to download the mosaic, its associated ancillary FITS files, and a list of the DCE numbers for the DCEs that were used to create the mosaic. For example, entering "Arp220" in the "Single Object" field and clicking "Submit" in the GUI represented above will yield a results page with four separate sections: a 12 micron IRAS background image with the search position marked with crosshairs, "Source Table Results", "Listing of Image Metadata Table Results", and "Download Images (Overlays)". Screenshots of these sections are shown in the figures below.

**Collection: Imaging, Object: IC 4553**

*Your selected position (or click) is marked by the **green** crosshairs.  
Click on above image to re-center, or fine tune your Region Size and/or Coordinate below. See results tables below for key to color overlays.*

<b>Coordinate/Object:</b>	<input type="text" value="15h 34m 57.27s +23d 30m 10.5s Equ J2000"/>	
<b>Size (deg):</b> [maximum 0.6 deg]	<input type="text" value="0.3"/>	<input type="checkbox"/> Images must cover coordinate
<b>Source Search Radius:</b> [maximum 0.3 deg]	<input type="text" value="0.15"/> <span style="border: 1px solid gray; padding: 2px;">deg</span>	<input type="checkbox"/> Search whole region
<input type="button" value="Submit"/> <input type="button" value="Reset"/>		
<input type="button" value="Back to Imaging Front Page"/>		

<p style="text-align: center;">15h 34m 57.27s +23d 30m 10.5s Equ J2000</p>	<p><b>Image Metadata:</b> <a href="#">Download</a> (36 image footprints)  <a href="#">Image</a> <a href="#">Metadata</a> (red overlays) [column key]</p>	<p><b>Background Image:</b> (factor of 1.5 larger than search size) <a href="#">Download</a> </p>
--	--	---

**Data Tag** string for Publication: [ADS/IRSA.Atlas#2012/0110/111022\\_19295](#)

[Bulk Download Script](#) of all results using WGET



Figure 3.6 Atlas search results: a 12 micron IRAS background image marked with crosshairs at the search position. Users will find it very useful to use the "Bulk Download Script" link above.

### Source Table Results


Source Table	Count	Table Type	Column Key	
<a href="#">dce.tbl</a> (small yellow overlays)	8	dcelist	<a href="#">Column Key</a>	

Figure 3.7 Atlas search results: Source Table Results. Clicking on "dce.tbl" will yield the table shown in Figure 3.10.

### Listing of Image Metadata Table Results



Image Metadata Table	Count	Type	Column Key	
<a href="#">science.tbl</a> [rectangular red footprints]	9	Original	<a href="#">Column Key</a>	
<a href="#">ancillary.tbl</a> [rectangular red footprints]	27	Original	<a href="#">Column Key</a>	

Figure 3.8 Atlas search results: metadata tables.

## Download Images (Overlays) [column key]

ra	dec	naxis1	naxis2	dataset	cutout	fname	Cutout Image	Entire Image
233.7163964	23.5036487	1512	2028	Enhanced	NO	images/5/50053/50053890 /50053890.50053890-0- short.IRAC.2.std.fits	<a href="#">To disk</a> <a href="#">/To OASIS</a>	same
233.7164184	23.5036487	1512	2028	Enhanced	NO	images/5/50053/50053890 /50053890.50053890-0.IRAC.3.mosaic.fits	<a href="#">To disk</a> <a href="#">/To OASIS</a>	same
233.7164184	23.5036487	1512	2028	Enhanced	NO	images/5/50053/50053890 /50053890.50053890-0.IRAC.4.unc.fits	<a href="#">To disk</a> <a href="#">/To OASIS</a>	same
233.7164184	23.5036487	1512	2028	Enhanced	NO	images/5/50053/50053890 /50053890.50053890-0.IRAC.1.std.fits	<a href="#">To disk</a> <a href="#">/To OASIS</a>	same
233.7163964	23.5036487	1512	2028	Enhanced	NO	images/5/50053/50053890 /50053890.50053890-0- short.IRAC.3.cov.fits	<a href="#">To disk</a> <a href="#">/To OASIS</a>	same
233.7163964	23.5036487	1512	2028	Enhanced	NO	images/5/50053/50053890 /50053890.50053890-0- short.IRAC.1.mosaic.fits	<a href="#">To disk</a> <a href="#">/To OASIS</a>	same
233.7299292	23.5464437	430	684	Enhanced	NO	images/5/50053/50053890 /50053890.50053890-0.MIPS.1.unc.fits	<a href="#">To disk</a> <a href="#">/To OASIS</a>	same
233.7164184	23.5036487	1512	2028	Enhanced	NO	images/5/50053/50053890 /50053890.50053890-0.IRAC.1.mosaic.fits	<a href="#">To disk</a> <a href="#">/To OASIS</a>	same
233.7164184	23.5036487	1512	2028	Enhanced	NO	images/5/50053/50053890 /50053890.50053890-0.IRAC.3.unc.fits	<a href="#">To disk</a> <a href="#">/To OASIS</a>	same
233.7163964	23.5036487	1512	2028	Enhanced	NO	images/5/50053/50053890 /50053890.50053890-0- short.IRAC.3.mosaic.fits	<a href="#">To disk</a> <a href="#">/To OASIS</a>	same
233.7163964	23.5036487	1512	2028	Enhanced	NO	images/5/50053/50053890 /50053890.50053890-0- short.IRAC.4.cov.fits	<a href="#">To disk</a> <a href="#">/To OASIS</a>	same
233.7163964	23.5036487	1512	2028	Enhanced	NO	images/5/50053/50053890 /50053890.50053890-0- short.IRAC.2.cov.fits	<a href="#">To disk</a> <a href="#">/To OASIS</a>	same
233.7164184	23.5036487	1512	2028	Enhanced	NO	images/5/50053/50053890 /50053890.50053890-0.IRAC.1.cov.fits	<a href="#">To disk</a> <a href="#">/To OASIS</a>	same
233.7163964	23.5036487	1512	2028	Enhanced	NO	images/5/50053/50053890 /50053890.50053890-0- short.IRAC.3.std.fits	<a href="#">To disk</a> <a href="#">/To OASIS</a>	same
233.7163964	23.5036487	1512	2028	Enhanced	NO	images/5/50053/50053890 /50053890.50053890-0- short.IRAC.1.unc.fits	<a href="#">To disk</a> <a href="#">/To OASIS</a>	same
233.7163964	23.5036487	1512	2028	Enhanced	NO	images/5/50053/50053890 /50053890.50053890-0- short.IRAC.4.std.fits	<a href="#">To disk</a> <a href="#">/To OASIS</a>	same
233.7164184	23.5036487	1512	2028	Enhanced	NO	images/5/50053/50053890 /50053890.50053890-0.IRAC.2.unc.fits	<a href="#">To disk</a> <a href="#">/To OASIS</a>	same
233.7164184	23.5036487	1512	2028	Enhanced	NO	images/5/50053/50053890 /50053890.50053890-0.IRAC.4.std.fits	<a href="#">To disk</a> <a href="#">/To OASIS</a>	same
233.7163964	23.5036487	1512	2028	Enhanced	NO	images/5/50053/50053890 /50053890.50053890-0- short.IRAC.2.unc.fits	<a href="#">To disk</a> <a href="#">/To OASIS</a>	same
233.7164184	23.5036487	1512	2028	Enhanced	NO	images/5/50053/50053890 /50053890.50053890-0.IRAC.1.unc.fits	<a href="#">To disk</a> <a href="#">/To OASIS</a>	same
233.7163964	23.5036487	1512	2028	Enhanced	NO	images/5/50053/50053890 /50053890.50053890-0- short.IRAC.4.mosaic.fits	<a href="#">To disk</a> <a href="#">/To OASIS</a>	same
233.7164184	23.5036487	1512	2028	Enhanced	NO	images/5/50053/50053890 /50053890.50053890-0.IRAC.4.mosaic.fits	<a href="#">To disk</a> <a href="#">/To OASIS</a>	same

Figure 3.9 Atlas search results: Images for download (truncated).

smid	regid	ra	dec	dcelist
50053890	50053890-0-short	233.738908	23.493234	<a href="#">IRAC Ch4 DCE list</a>
50053890	50053890-0	233.722812	23.521834	<a href="#">IRAC Ch1 DCE list</a>
50053890	50053890-0	233.738908	23.493234	<a href="#">IRAC Ch4 DCE list</a>
50053890	50053890-0-short	233.722812	23.521834	<a href="#">IRAC Ch1 DCE list</a>
50053890	50053890-0	233.739008	23.49338	<a href="#">IRAC Ch2 DCE list</a>
50053890	50053890-0-short	233.723191	23.521316	<a href="#">IRAC Ch3 DCE list</a>
50053890	50053890-0-short	233.739008	23.49338	<a href="#">IRAC Ch2 DCE list</a>
50053890	50053890-0	233.723191	23.521316	<a href="#">IRAC Ch3 DCE list</a>

Figure 3.10 Screenshot of dce.tbl. Clicking on one of the "DCE list" links in the final column will yield a list of DCE numbers that correspond to the BCDs that were used to create the mosaic indicated by the Super Mosaic ID and Region ID listed in the first two columns.

### 3.7.2 Mosaic access through the Cutout Service

The Cutouts Service provides access to small sections of a Super Mosaic. You can access the Spitzer Enhanced Imaging Mosaic data using the Cutouts Service at [http://irsa.ipac.caltech.edu/data/SPITZER/Enhanced/Imaging/index\\_cutouts.html](http://irsa.ipac.caltech.edu/data/SPITZER/Enhanced/Imaging/index_cutouts.html)

It looks like this:



<input checked="" type="radio"/> <b>Single Location</b>	<p><b>Coordinate/Object:</b> <input type="text"/></p> <p><b>Cutout Size:</b> <input type="text" value="0.25"/> (deg) [range: 0.005-0.5 deg]</p> <p><b>Coordinate Examples:</b></p> <ul style="list-style-type: none"> <li>• 335.08 59.19 eq</li> <li>• 22h20m20.0s 59d11m26s Equ J2000</li> <li>• 104.638 1.795 ga</li> </ul> <p><b>Default:</b> Equatorial J2000 </p> <p>NOTE: For single cutouts of Imaging data larger than 0.5 deg, you can use <a href="#">Atlas</a>, where the search size acts as your cutout size, up to 0.6 degrees.</p>
<input type="radio"/> <b>Multiple Positions</b> (User Table Upload)	<p><b>Table Upload Instructions:</b> The input table should contain a list of coordinates or astronomical object names; a (cutout) size column is optional. Please see <a href="#">allowed table format</a> information. A cutout size may be specified in a column in the input table, allowing for a different cutout size per position. Or, to have the same size cutouts for all input positions, specify one value in the <b>Uniform Cutout size</b> field below. <a href="#">Example table</a>.</p> <p><b>Table </b>: <input type="text"/> <input type="button" value="Browse..."/></p> <p><b>Uniform Cutout size (deg)</b> [range: 0.005-0.5 deg]: <input type="text" value="0.25"/></p> <p>Or, specify a non-uniform cutout size here for each position in the table using a cutout size column name:</p> <p><b>Cutout size column name:</b> <input type="text"/></p>

Figure 3.11 Spitzer Enhanced Imaging Cutouts Service

## Chapter 4. Source List

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This chapter describes the generation and characteristics of the Source List that is created from the Enhanced Super Mosaics. The procedure starts with the generation of single-band source lists for each of the IRAC channels and for MIPS 24 micron data. These single-band Source Lists are then bandmerged together and associated with the 2MASS Point Source Catalog to produce the final Spitzer Enhanced Imaging Source List. Each of these steps is described in the sections below.

### 4.1 Creation of IRAC Single-Band Source Lists

Single-Band Source Lists are created for each of the four IRAC channels. A flowchart describing the procedure for generating a Single-Band IRAC Source List is provided in Figure 4.4 A . First, the 2MASS Point Source catalog is queried for each mosaic, and a bright source mask is generated for each band. Then SExtractor is run on the images with a very large smoothing kernel and detection size and the segmentation map is used to mask extended sources and extended emission. Next, SExtractor is run on each set of images three times, with different detection settings tuned for detecting sources in “normal” regions, regions of bright extended emission, and regions around bright sources. The bright and extended source masks are used to select sources from the appropriate SExtractor run for the final IRAC Single-Band Source Lists. The SExtractor setting for each object is recorded in the FluxFlag columns: 0 = normal 1=extended, 2=bright. If a source is in both a bright star and extended source mask, FluxFlag=2.

Extended sources in the single-band IRAC lists are then flagged by separately running SExtractor on the mean images with settings tuned to detect large objects. The SExtractor segmentation map from this process is then used to create an extended source mask. For each source, the fraction of pixels falling within an extended source mask is computed and recorded in the ExtFrac columns of the Source List. Any source which has most of its pixels within an extended source mask is flagged in the FluxFlags columns of the Source List.

Bright sources are also flagged in each single-band list. Assuming that bright 2MASS stars will also be bright in all IRAC bands, bright 2MASS sources are used to generate bright source masks for the IRAC mosaics. The mask consists of a circular region of a size determined by the K band magnitude and IRAC channel along with a rectangular region aligned along the mean PA of the mux-bleed for the brightest sources. The radius of the circular region goes as

$$r = K \times m + b,$$

where  $K$  is the 2MASS K-band magnitude,  $m = -5.48$  for IRAC and 47.3 for MIPS, and  $b$  depends on the *ObsType* as shown in Table 4.1.

**Table 4.1 Zeropoint of bright mask radius-magnitude relation.**

<b>Instrument</b>	<b><i>ObsType</i></b>	<b>b</b>
IRAC	0, 4, 5, 6, 7	70
IRAC	1, 2, 3	80
MIPS	All	6

There is also a cutoff beyond which no mask is made based on channel and *ObsType*. These are listed in Table 4.2.

**Table 4.2 Bright Mask Magnitude Cut-offs beyond which no Bright mask is made.**

<b><i>ObsType</i></b>	<b>Ch1 (AB mag)</b>	<b>Ch2 (AB mag)</b>	<b>Ch3 (AB mag)</b>	<b>Ch4 (AB mag)</b>
0	9.5	9.5	9	8
1	14	14	10	10
2	14	14	10	10
3	14	14	10	10
4	9.5	9.5	9	8
5	14	14	10	10
6	9.5	9.5	9	8
7	14	14	10	10

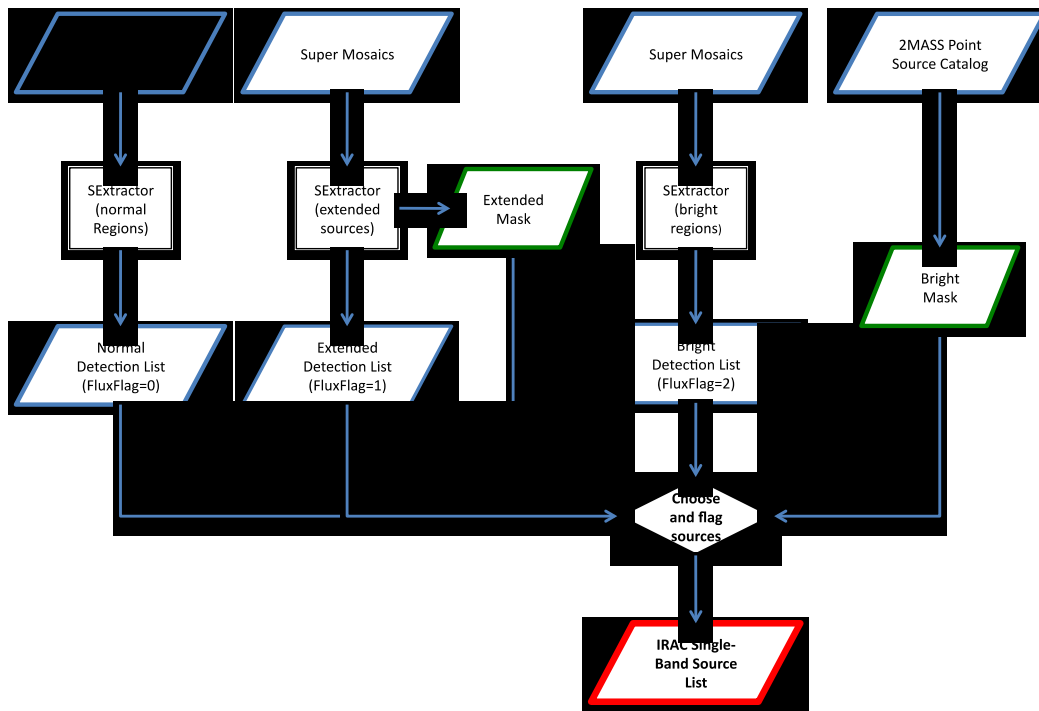
For IRAC there is also a rectangular muxbleed mask applied to stars brighter than a certain magnitude at the mode of the PA for each mosaic. These limits are given in Table 4.3.

**Table 4.3 Magnitude thresholds for applying rectangular muxbleed masks around bright stars.**

<b><i>ObsType</i></b>	<b>Ch1 (AB mag)</b>	<b>Ch2 (AB mag)</b>	<b>Ch3 (AB mag)</b>	<b>Ch4 (AB mag)</b>
0	9.5	9.5	9	8
1	10	10	6	6
2	10	10	6	6
3	10	10	6	6
4	9.5	9.5	9	8
5	10	10	6	6
6	9.5	9.5	9	8
7	10	10	6	6

Objects that were detected in regions covered by a bright source mask were flagged in the Source List. For each source, the fraction of pixels falling within the bright mask is recorded in the BrtFrac columns of the Source List. If over fifty percent of the pixels within a given source fall within a bright mask, then the source is flagged in the FluxFlag columns of the Source List.

SExtractor is run using the median images as the detection image, the standard deviation image as the absolute RMS noise map for the detection image, and the mean mosaic and uncertainty map as the photometry measurement and absolute RMS noise map for the photometry respectively.



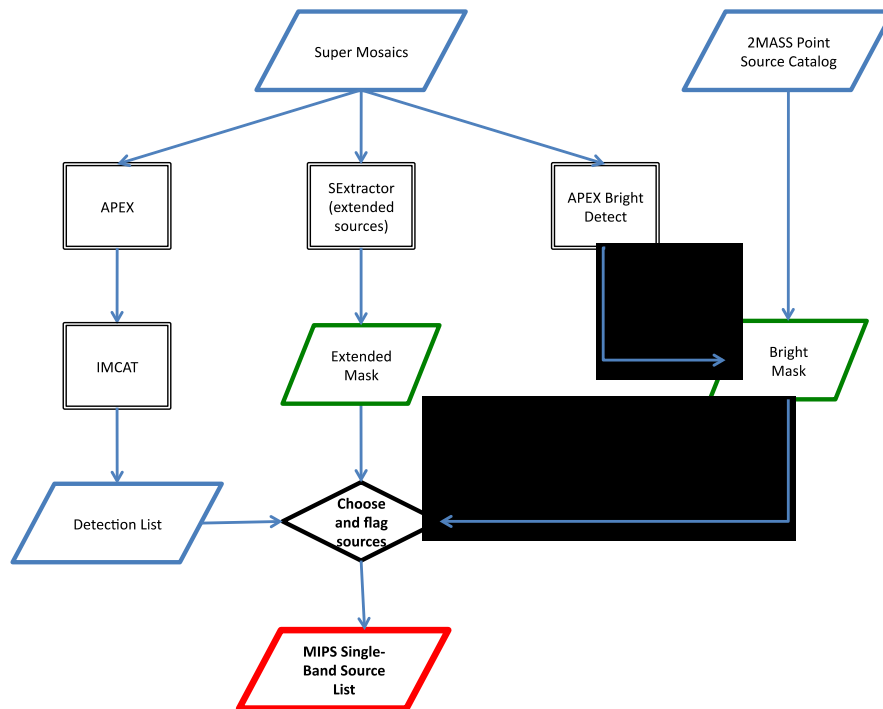
**Figure 4.1** Flowchart describing creation of IRAC Single-Band Source Lists. The input Super Mosaics are the Median and Standard Deviation Mosaics for detection with SExtractor, and the Mean and Uncertainty Mosaics for photometry with SExtractor.

## 4.2 Creation of MIPS Source List

The MIPS Source List was created using MOPEX/APEX rather than SExtractor. This is because SExtractor does not provide PSF-fit photometry, while APEX does. PSF-fit photometry on mosaics is not recommended for IRAC because the PSF is not axisymmetric and is under-sampled by the pixel scale. As a result, it can not be generically performed on combined data.

SExtractor was used to generate an extended source mask in the same way as the IRAC catalog by detecting on the mean mosaic and using the segmentation map to create an extended source mask. In addition to 2MASS the APEX bright-detect detection map was used to mask bright sources in MIPS since many bright 24 micron sources are too faint to appear in the 2MASS catalog.

APEX takes three images as input: the mean, uncertainty, and coverage mosaics. The output list of APEX detections is then fed into IMCAT “apphot” to measure the FWHM of the detections on the mean mosaic. The FWHM is used to flag detected sources that are too small, large, peaky, or asymmetric. Sources that are affected by a nearby extended source are flagged in the ExtFrac column of the MIPS Source List. The APEX Bright Detect module is used to detect bright sources in the mosaics. Along with the positions of bright 2MASS sources, the results are used to create a bright source mask. Sources affected by a nearby bright source are flagged in the BrtFrac column of the 24 micron Source List.



**Figure 4.2** Flowchart describing steps to create the MIPS Single-Band Source List. The input Super Mosaics include the Mean, Uncertainty, and Coverage Mosaics. APEX is used for source detection, while IMCAT is used to measure shape parameters.



### 4.3 Bandmerging Single-Band Source Lists to create the final Spitzer Source List

Once the Single-band Source Lists are created using the procedures described above, they are merged together, along with the 2MASS catalog, to create the final Source List. The general procedure is described in the flowchart in Figure 4.4 A .

First, detections with  $S/N > 3$  in the Single-Band IRAC Source Lists are matched together, based on position. The closest match within 1 arcsec is selected. The following flags are set:

**Table 4.4 Criteria for IRAC Sources in Source List.**

Source List Requirement	Explanation
FWHM > 1.2 arcsec.	Rejects small objects that are likely spurious.
FWHM < 3.6 arcsec.	Rejects large objects that are likely extended.
Peak Mag - AP Mag > 2.7.	Rejects highly peaked objects that are likely spurious.
Peak Mag - AP Mag < 3.2.	Rejects broad source that are likely extended.
Peak - Centroid < 0.9 arcsec.	Rejects asymmetric source that are likely blended.

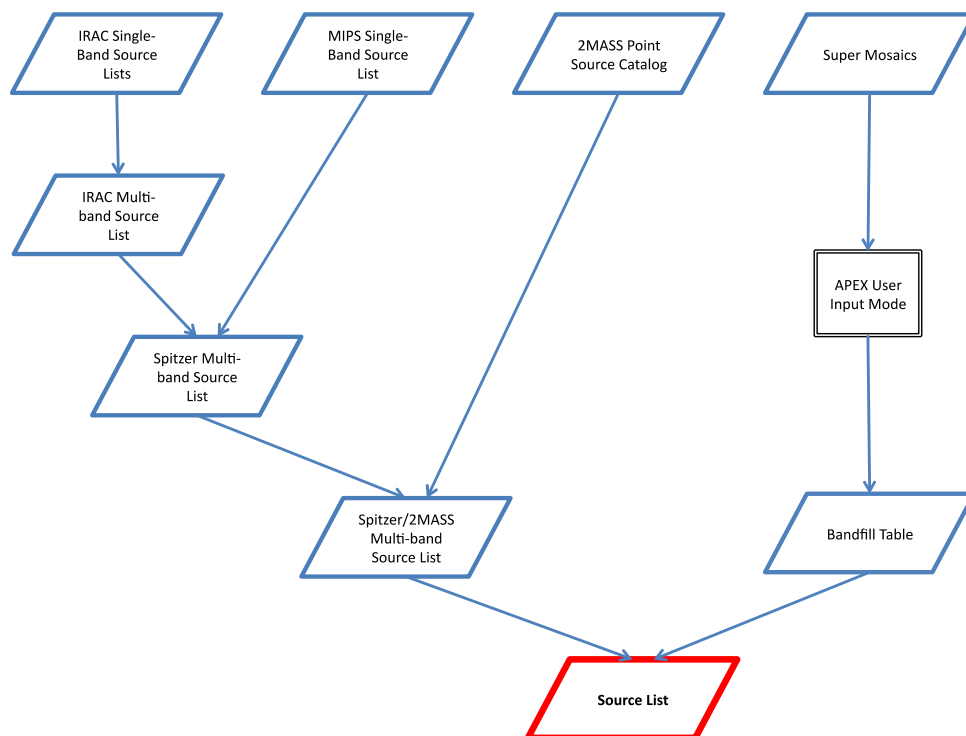
If MIPS data exist, the MIPS detections with  $S/N > 3$  are then merged to the best IRAC positions (shortest-wavelength IRAC detection with  $S/N > 10$ ) within 3 arcsec. Again the closest positional match is used. Objects are then flagged based on the  $S/N$ , coverage, and FWHM of the MIPS detection along with the presence of an IRAC detection. If an object passes the IRAC flagging and has a  $S/N$  of  $> 10$  in either an IRAC channel or MIPS it is placed in the “object” list and the shortest wavelength detection is used as the position.

Next the 2MASS catalog is merged with the “object” list using a 1” match radius, with the closest object being chosen. After merging with 2MASS, all detections in the “object” list are placed on a grid.

If a source in the multi-band Spitzer Source List is deemed real, but not detected individually in all bands, the flux density is measured in the remaining bands using the APEX-1-frame module to provide measurements and/or upper limits. After matching the various detections, APEX in user-input mode is used to perform aperture photometry on all images, and PSF fit photometry on the MIPS image in a similar way to the direct detection catalogs. The entire “object” list is used to ensure the best possible de-blending. Any object that does not have a direct detection in a given band but has a flux measured at a  $S/N > 3$  has this flux placed in the “BandFill columns”. If the object is not detected at a  $S/N > 3$  then the 3 sigma upper limit is placed in the “limits” column. Note that any given channel will have either a detection flux density, a bandfill flux density, or an upper limit; never more than one of these. The type of flux is recorded in the *Fluxtype* column.

The IRAC Source List is then positionally matched to the MIPS Source List. The resulting Source List is then matched to the 2MASS Point Source Catalog. Objects that are detected in fewer than

two IRAC bands are removed from the Source List. For each remaining object, APEX is used to perform photometry at the position dictated by the shortest-wavelength channel with a better than ten sigma detection. If these measurements are greater than 3 sigma, they are recorded in the bandfill (\*\_bf) columns of the Source List. If these measurements are of lower signal-to-noise, they are used to determine the three-sigma flux upper limits recorded in the \*\_3siglim columns of the Source List.



**Figure 4.3** Flowchart describing processing steps required to bandmerge IRAC and MIPS lists.

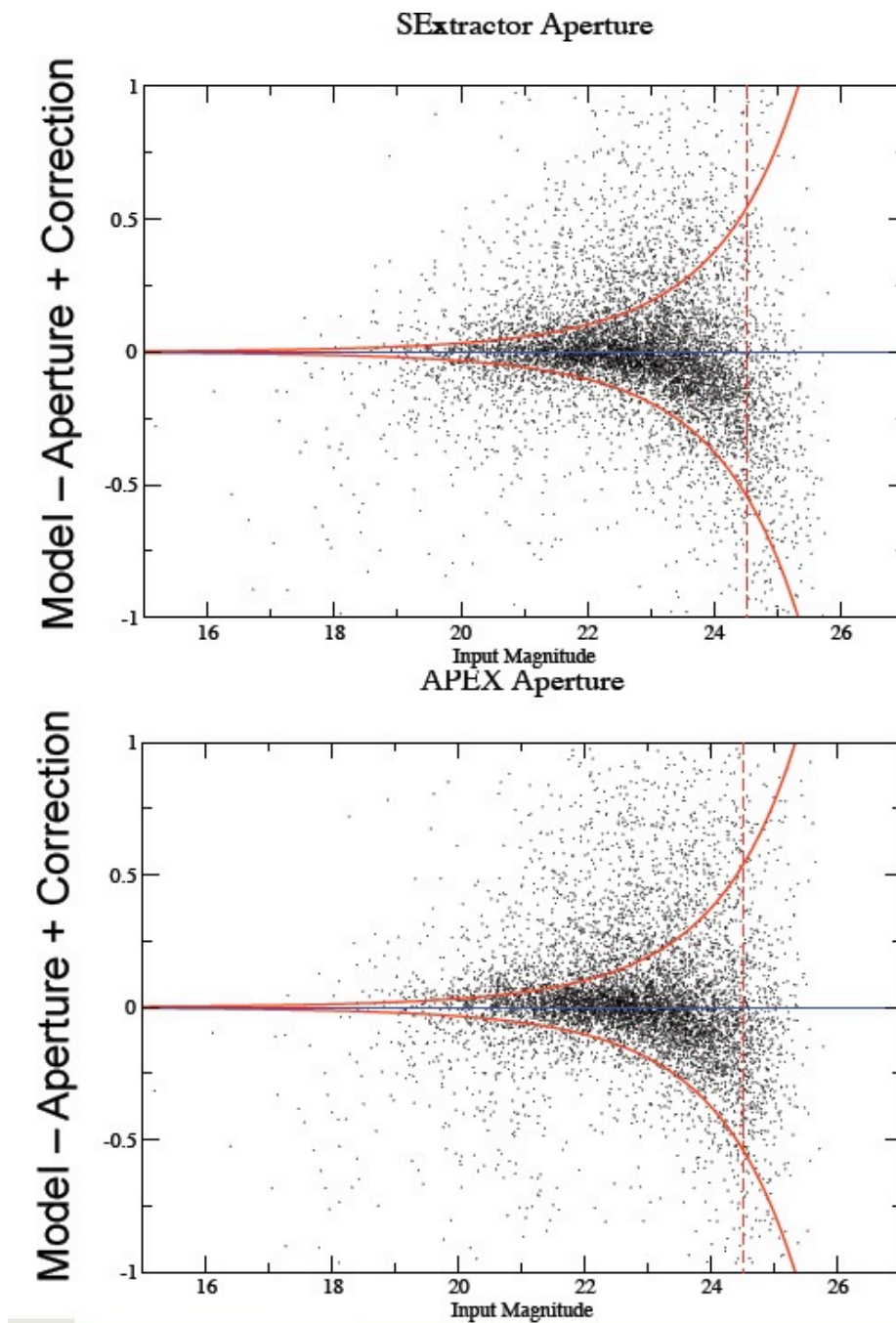
#### 4.4 APEX versus SExtractor

APEX is needed for MIPS PSF fitting. Otherwise, SExtractor was used while being careful about the noise calculations.

	<b>APEX</b>	<b>SExtractor</b>
Speed	Now Fast (improved)	Fast
PSF fit photometry	Yes	No
Aperture flux correction for blending	No	Yes
Shape parameters	No	Yes
Use coverage map for gain	Yes	No

**Table 4.5 Summary of differences between APEX and SExtractor.**

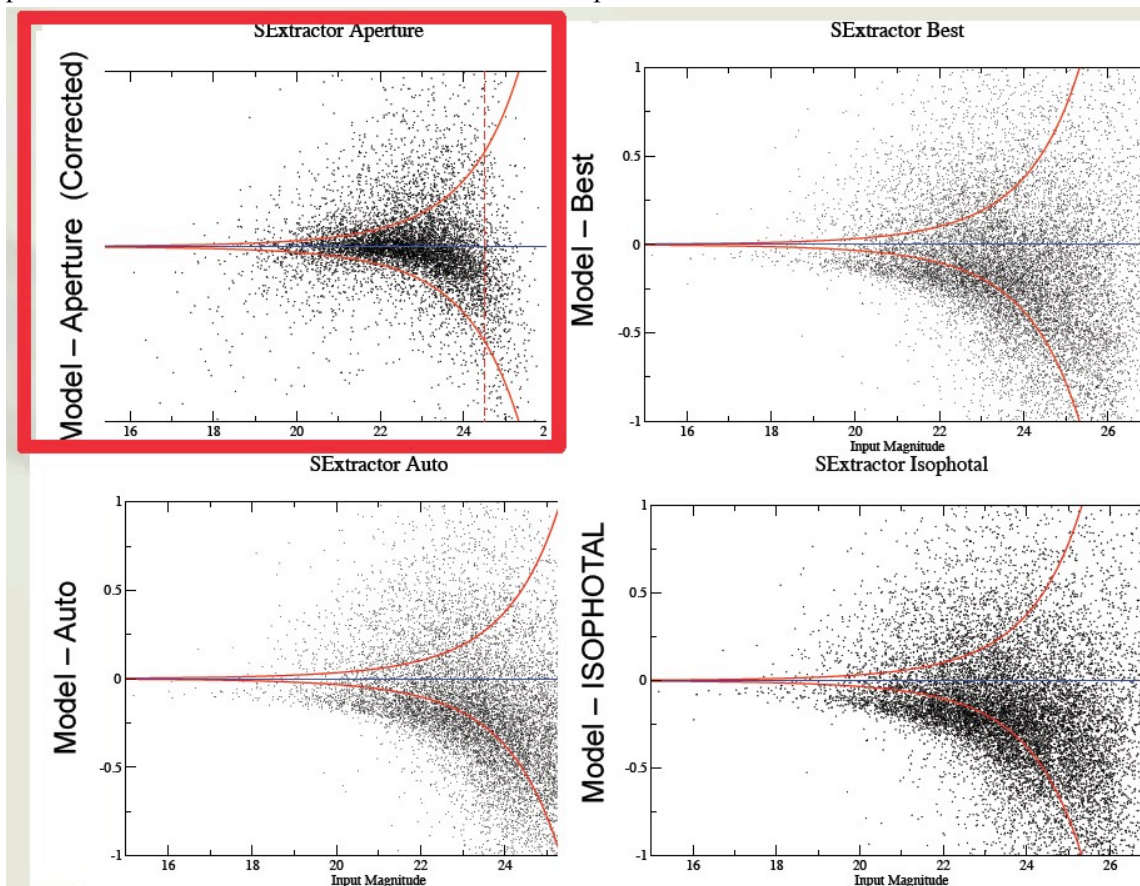
APEX and SExtractor produce similar results for corrected aperture photometry.



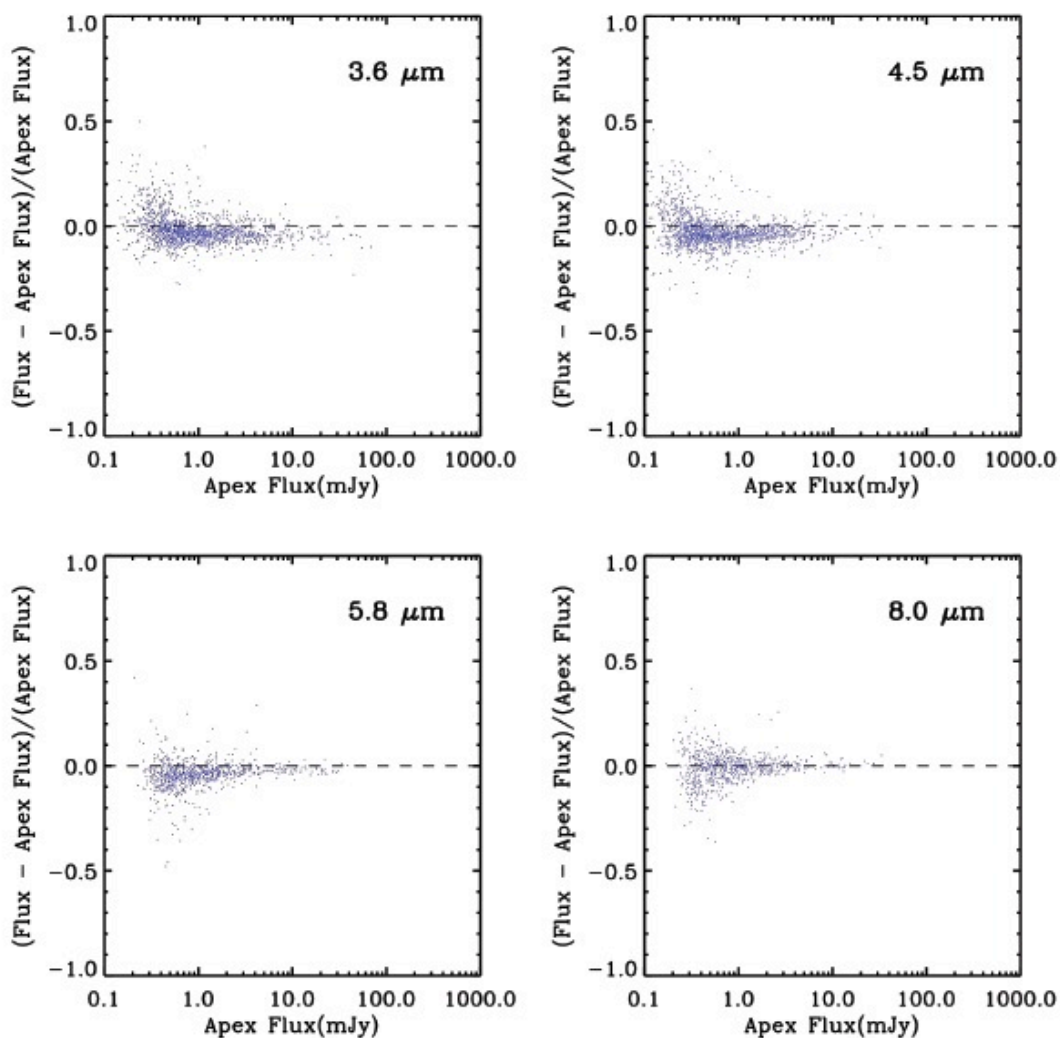
**Figure 4.4** A comparison between SExtractor (top) and APEX (bottom) corrected aperture magnitudes. The two programs produce very similar results. SExtractor produces fewer sources above the 1-sigma line due to deblending. The turn-down at faint magnitudes is due to confusion affecting background subtraction. This is unavoidable without detailed simulations and a high-resolution prior.

## 4.5 Aperture Photometry

Millennium Simulation sizes and magnitudes were used to simulate IRAC data. SExtractor was used to calculate several types of photometry: corrected aperture photometry, "Best" magnitudes, Auto magnitudes, and ISOPHOTAL magnitudes. Fixed aperture magnitudes corrected to total magnitudes were found to provide the best flux estimate. The only way to do better is if an HST prior is available or if the source is known to be a point source.



**Figure 4.5 Comparison between different SExtractor magnitude types. A fixed aperture magnitude corrected to a total magnitude provides the best match to simulated model magnitudes.**



**Figure 4.6** A comparison between Source List SEExtractor corrected aperture fluxes and APEX PRF fluxes in a crowded galactic field. Source List aperture photometry agrees with verified APEX PRF fluxes to 5%. The offset is a background estimation effect, due to the difficulty in estimating backgrounds in crowded fields.

#### 4.6 Zero points for computing magnitudes

The zeropoints for computing magnitudes are provided in Table 4.6, where magnitudes =  $-2.5 * \log_{10}(f/\text{zeropoint})$ . Please see the [IRAC Instrument Handbook](#) and the [MIPS Instrument Handbook](#) for details on these zeropoints. The zeropoints on both the AB and Vega systems are recorded in the image headers.

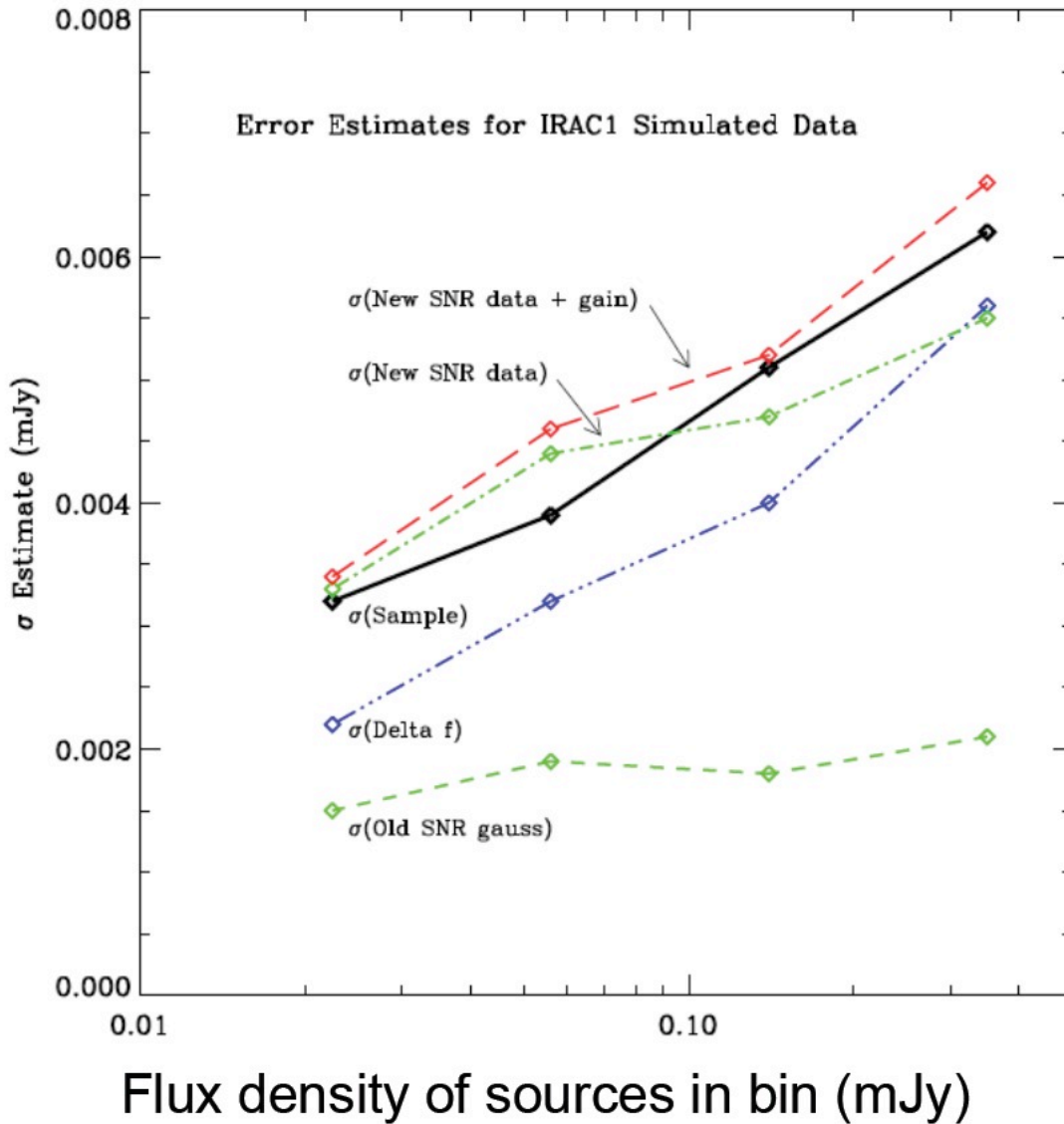
**Table 4.6 Zeropoints for computing magnitudes.**

<b>Wavelength (micron)</b>	<b>Zeropoint (Jy)</b>	<b>zeropoint error (Jy)</b>
IRAC 3.6	280.9	4.1
IRAC 4.5	179.7	2.6
IRAC 5.8	115.0	1.7
IRAC 8.0	64.9	0.9
MIPS 24	7.17	0.11

## 4.7 Flux Uncertainties

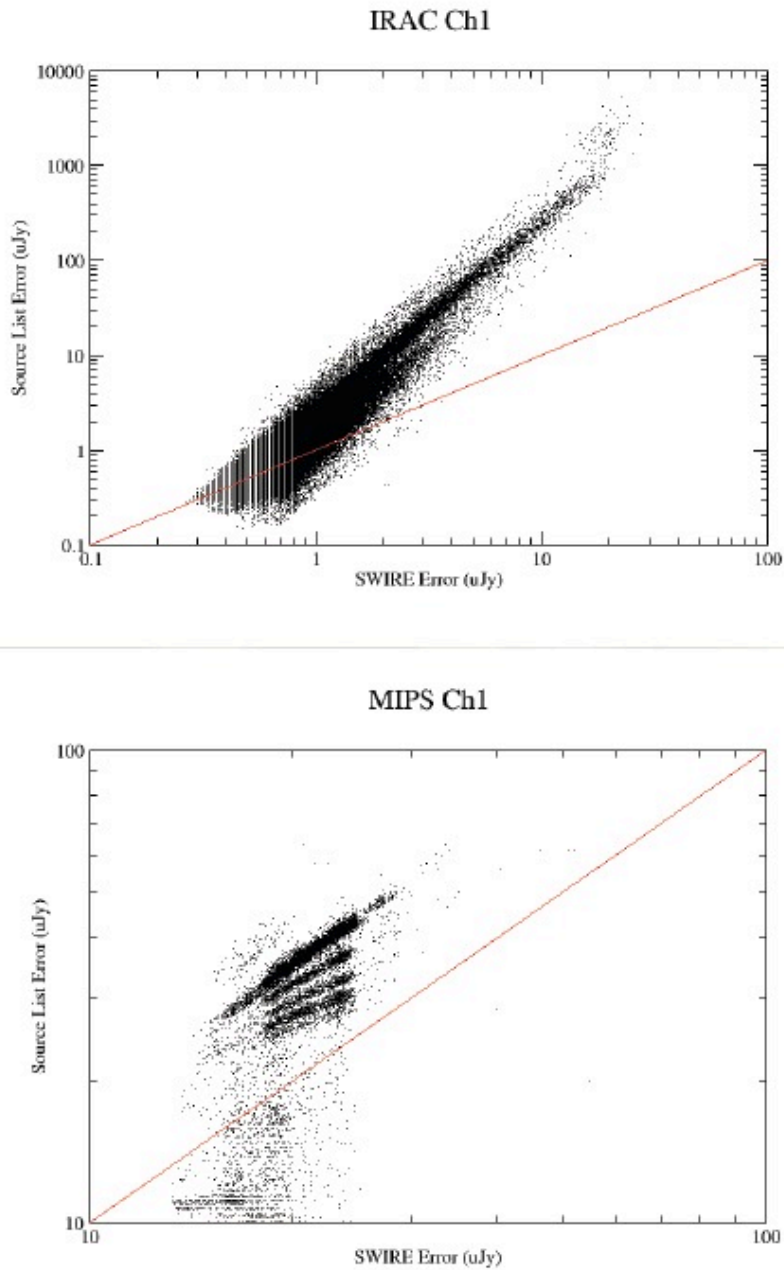
Measuring noise on mosaics is very tricky because re-sampling correlates noise and leads to an underestimate of the true error. Also, gain changes with coverage and exposure time, so can vary across a mosaic.

APEX properly calculates the noise for Spitzer images, taking into account coverage, gain, and the noise map. However, the default behavior of SExtractor is to estimate noise on the input image and assume a gain that varies as the ratio of the measured noise to the noise map. This method significantly underestimates the noise for resampled images. We have tuned SExtractor to estimate the true noise by using absolute uncertainty maps, no gain scaling, and a gain calculation based on the exposure time and mean coverage in the mosaics. As a result, Spitzer Source List errors will typically be larger than those produced by Legacy Teams, especially at bright fluxes. The mean gain used is recorded in the image headers.



**Figure 4.7** Flux density noise estimates from IRAC Channel 1 (3.6 micron) simulated data. The true noise is shown as a black solid line. Additional estimates available within MOPEX are also shown: 1) old SNR with Gaussian background noise (green, short dash); 2) Delta flux (blue, dot-dot-dot-dash); 3) new SNR with Gaussian noise, but no gain-corrected source photon noise (blue, long dash); 4) new SNR with Gaussian noise, with gain-corrected source photon noise (green, dot-dash); and 5) new SNR with data uncertainties (red, long dash). See the [MOPEX documentation](#) for details. Because of IRAC undersampling, some error estimates can underestimate the true noise. The method adopted for the Source List uses the top estimate to provide a conservative estimate when MOPEX is used, and uses proper noise maps and gain factors when SExtractor is used.





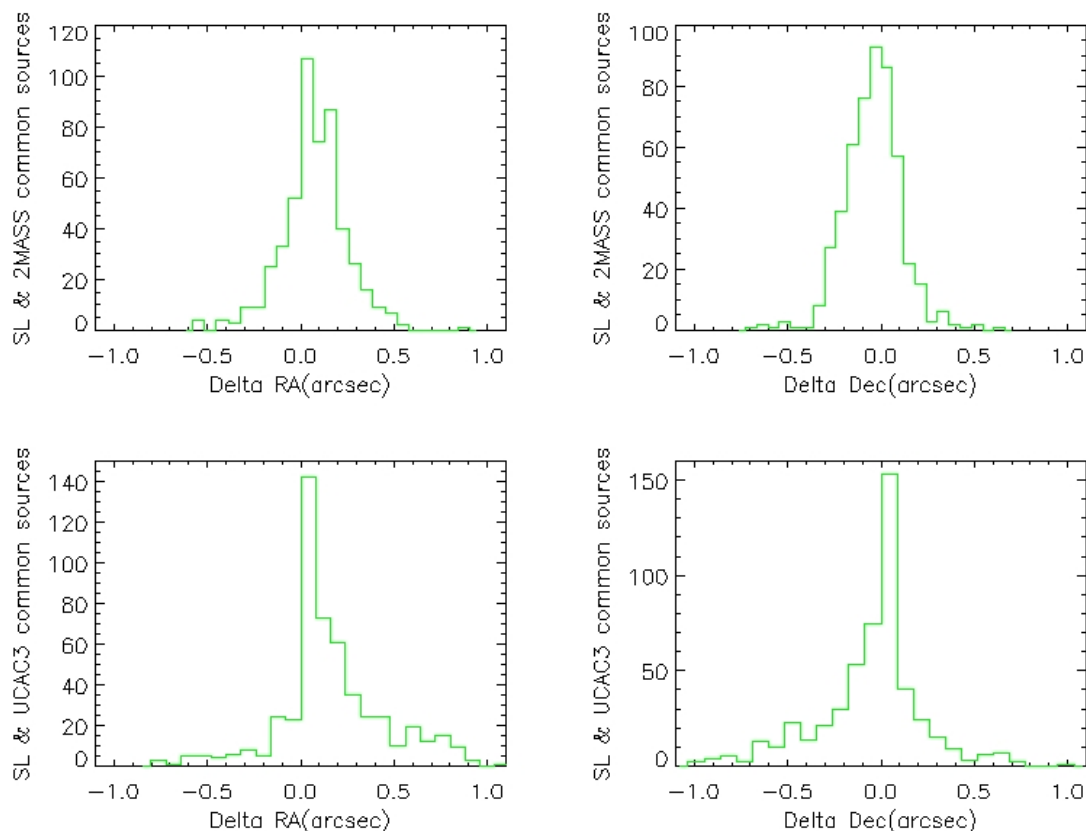
**Figure 4.8** A comparison of the errors estimated for the Spitzer Source List and those generated by the SWIRE Legacy Survey Team. Source List errors tend to be significantly higher due to the proper use of noise maps and gain in SExtractor.

## 4.8 Astrometry

The astrometry of the Source List was checked against both the 2MASS and UCAC3 catalogs using 5000 point sources that are well-detected in all bands of the Spitzer Enhanced Imaging Mosaics of the Taurus Molecular Cloud. These sources were matched to the 2MASS and UCAC3 catalogs using a 1 arcsec matching radius. The median positional offsets between the Source List and the 2MASS and UCAC3 catalogs are very small, approximately a tenth of the IRAC beamsize of 2 arcsec. See Table 4.7 and Figure 4.8. Note that the IRAC astrometry with respect to 2MASS has systematics at the 0.3 arcsec level after superbordersight refinement. The SL astrometry is well within this systematic uncertainty.

**Table 4.7 Astrometric comparison between SL, 2MASS, and UCAC3 using approximately 500 stars in the Taurus Molecular Cloud. All units are arcseconds.**

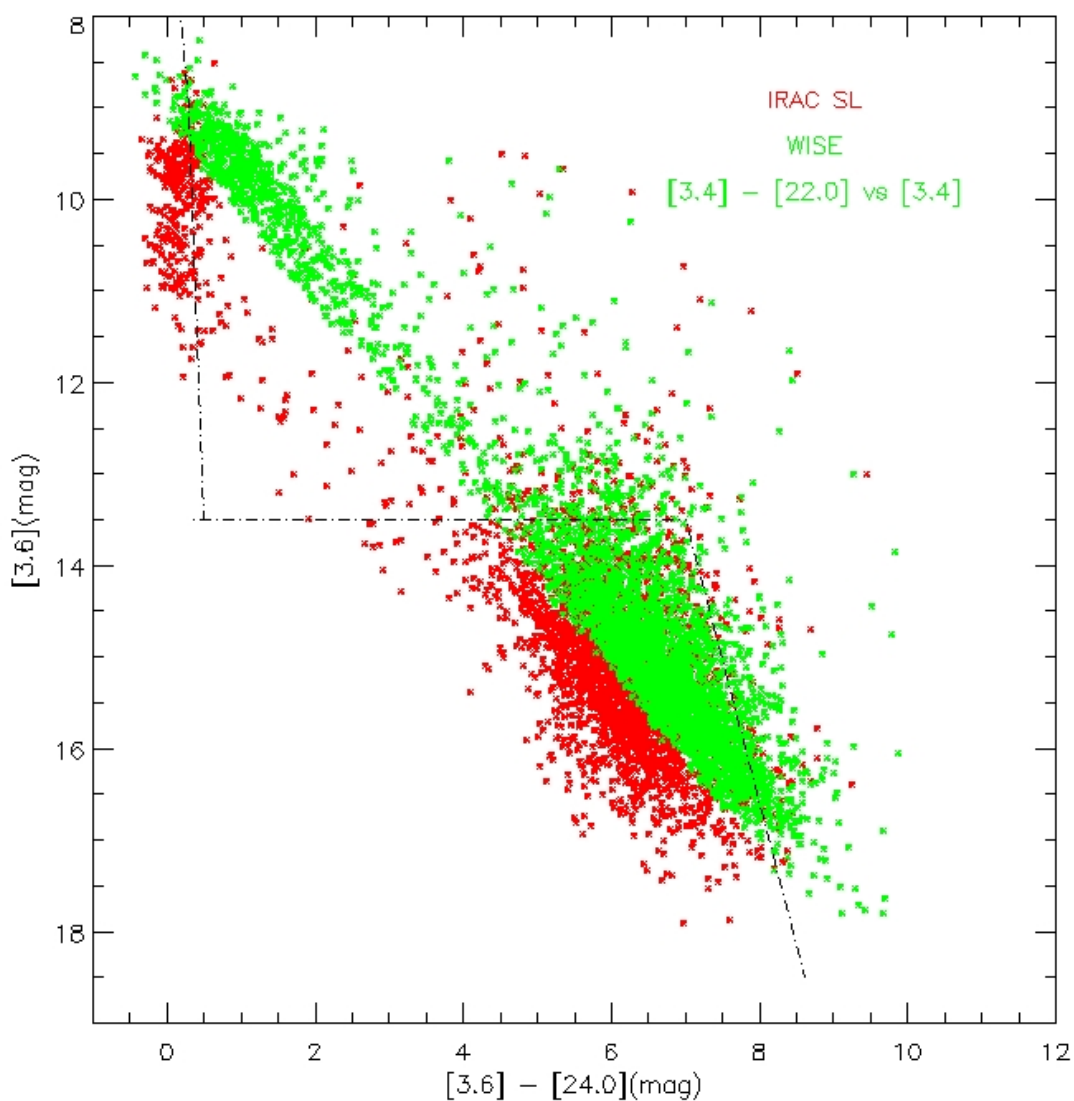
	<b>Mean (arcsec)</b>	<b>Median (arcsec)</b>	<b>Standard Deviation (arcsec)</b>
<b>RA(SL) - RA(2MASS)</b>	0.071	0.082	0.177
<b>DEC(SL) - DEC(2MASS)</b>	-0.044	-0.034	0.157
<b>RA(SL) - RA(UCAC3)</b>	0.153	0.1098	0.293
<b>DEC(SL) - DEC(UCAC3)</b>	-0.063	0.000	0.279



**Figure 4.9 Comparison between Source List and 2MASS positions (top) and between Source List and UCAC3 positions (bottom) for approximately 5000 point sources in the Taurus Molecular Cloud that are well-detected in all Source List bands.**

## 4.9 Comparison with WISE

Starting with a sample of approximately 5000 well-detected sources from the Taurus Legacy Survey, about 4000 were found in both the SL and WISE, with about 400 sources found in the SL that were not found in WISE. The differences in the number of identified sources partially arise from different sensitivity limits, angular resolution, and coverage of the Taurus Molecular Cloud in the WISE Preliminary Release. The sensitivity limits of the Legacy catalog are, for instance, 0.038 and 2.4 mJy at 3.6 and 24 micron, respectively. In comparison the sensitivity limits of WISE are 0.08 and 6.0 mJy at 3.4 and 22 microns, respectively. The Spitzer Space Telescope angular resolution is approximately three times that of WISE at shorter wavelengths (2 arcsec at 3.6 micron versus 6 arcsec at 3.5 micron), and twice at longer wavelengths (6 arcsec at 24 micron versus 12 arcsec at 22 micron). Figure 4.10 shows a color magnitude diagram created from both SL and WISE photometry. Astronomically, one sees the same trends in both SL and WISE colors, even without applying any color corrections.



**Figure 4.10 Comparison between IRAC SL (red) and WISE (green) photometry for approximately 4000 sources in the Taurus Molecular Cloud. No color corrections have been applied. Objects to the left of the dot-dashed line tend to be extragalactic. Objects to the right include Young Stellar Objects.**

#### 4.10 Content of Source List

The Table below describes all of the columns available in the Source List. For all quantities, the null values are the string "null".

**Table 4.8 Description of columns in Source List.**

Column Name	Format	Units	Description
objid	string	none	Object Identification Number. Sexagesimal, equatorial position-based source name in the form: <b>hhmmss.ss+ddmmss.s</b> . The full naming convention for the Spitzer Source List Preliminary Release sources has the form <b>"SSTSLP Jhhmmss.ss+ddmmss.s"</b> where <b>"SSTSLP"</b> indicates the source is from the Preliminary Release Source List, and <b>"J"</b> indicates the position is J2000.  <b>CAUTION:</b> The objid should not be used as an astrometric reference. It is not a substitute for the source position information in the ra and dec columns.
ra	float	deg	Right Ascension (J2000) of the shortest wavelength ten-sigma Spitzer detection.
dec	float	deg	Declination (J2000) of the shortest wavelength ten-sigma Spitzer detection.
l	float	deg	Galactic Longitude
b	float	deg	Galactic Latitude
nmatches	int	none	Number of possible matches
nreject	int	none	Number of possible matches rejected
nbands	int	none	The number of Spitzer bands that have ten-sigma detections (ap1 for IRAC, PSF flux density for MIPS 24), plus 1 if there is a 2MASS association, plus 1 if there is a WISE association.

i1_fluxtype	int	none	<p>The type of measured flux density that is available for IRAC channel 1.</p> <ul style="list-style-type: none"> <li>• <b>i1_fluxtype = 0:</b> there is no IRAC channel 1 imaging data available and no flux densities are available.</li> <li>• <b>i1_fluxtype=1:</b> a 3-sigma source was detected in IRAC channel 1, and measured flux densities can be found in the columns i1_f_ap1 and i1_f_ap2.</li> <li>• <b>i1_fluxtype=2:</b> there was not a ten-sigma source detected in channel 1, but a &gt;3-sigma Bandfill flux density was measured at ra, dec and can be found in i1_f_ap1_bf and i1_f_ap2_bf.</li> <li>• <b>i1_fluxtype=3:</b> 3-sigma upper limits are recorded in the columns i1_f_ap1_3siglim and i1_f_ap2_3siglim.</li> <li>• <b>i1_fluxtype=4:</b> the source is bright and detected in multiple bands, but fails to meet the size criteria; this source is real, but its flux density cannot be measured accurately, so it is not reported.</li> </ul>
i2_fluxtype	int	none	Same as for i1_fluxtype, but for IRAC channel 2.
i3_fluxtype	int	none	Same as for i1_fluxtype, but for IRAC channel 3.
i4_fluxtype	int	none	Same as for i1_fluxtype, but for IRAC channel 4.
m1_fluxtype	int	none	<p>The type of measured flux density that is available for MIPS channel 1.</p> <ul style="list-style-type: none"> <li>• <b>m1_fluxtype = 0:</b> there is no MIPS channel 1 imaging data available and no flux densities are available.</li> <li>• <b>m1_fluxtype=1:</b> a 10-sigma source was detected in MIPS channel 1, and measured flux densities can be found in the columns m1_f_ap and m1_f_psf.</li> <li>• <b>m1_fluxtype=2:</b> there was not a 10-sigma source detected in channel 1, but a &gt;3-sigma Bandfill flux density was measured at ra, dec and can be found in m1_f_ap_bf and m1_f_psf_bf.</li> <li>• <b>m1_fluxtype=3:</b> three-sigma upper limits are recorded in the columns m1_f_ap_3siglim and m1_f_psf_3siglim.</li> </ul>

i1_fluxflag	int	none	<ul style="list-style-type: none"> <li>• <b>i1_fluxflag=0</b>: the object lies in a normal region of the IRAC channel 1 Super Mosaic</li> <li>• <b>i1_fluxflag=1</b>: the object lies in the vicinity of an extended source</li> <li>• <b>i1_fluxflag=2</b>: the object lies in the vicinity of a bright source and possibly also an extended source.</li> </ul>
i2_fluxflag	int	none	Same as i1_fluxflag, except for IRAC channel 2.
i3_fluxflag	int	none	Same as i1_fluxflag, except for IRAC channel 3.
i4_fluxflag	int	none	Same as i1_fluxflag, except for IRAC channel 4.
m1_fluxflag	int	none	Same as i1_fluxflag, except for MIPS channel 1.
i1_softsatflag	int	none	IRAC channel 1 (3.8 micron) soft saturation flag. This flag is nonzero if the source suffers from nonlinear pixels. See Section 1.1.353907162.
i2_softsatflag	int	none	Same as i1_softsatflag, except for IRAC channel 2 (4.5 micron).
i3_softsatflag	int	none	Same as i1_softsatflag, except for IRAC channel 3 (5.8 micron).
i4_softsatflag	int	none	Same as i1_softsatflag, except for IRAC channel 4 (8 micron).
i1_f_ap1	float	uJy	IRAC channel 1 flux density measured within an aperture of diameter 3.8 arcsec and corrected to infinite radius. This column will have a non-null value only if the detection is at a significance greater than 10 sigma.
i1_df_ap1	float	uJy	Uncertainty in i1_f_ap1.
i1_f_ap2	float	uJy	IRAC channel 1 (3.6 micron) flux density measured within an aperture of diameter 5.8 arcsec and corrected to infinite radius. This column will have a non-null value only if the detection is at a significance greater than 10 sigma.
i1_df_ap2	float	uJy	Uncertainty in i1_f_ap2.
i1_f_ap1_bf	float	uJy	IRAC channel 1 (3.6 micron) bandfill flux density measured at the position ra, dec within an aperture of diameter 3.8 arcsec. This column will have a non-null value if the original detection was less significant than 10 sigma and the bandfill flux density is significant at a level greater than 3 sigma.
i1_df_ap1_bf	float	uJy	Uncertainty in i1_f_ap1_bf.
i1_f_ap2_bf	float	uJy	IRAC channel 1 (3.6 micron) bandfill flux density measured at the position ra, dec within an aperture of diameter 5.8 arcsec. This column will have a non-null value if the original detection was less significant than 10 sigma and the bandfill flux density is significant at a level greater than 3 sigma.
i1_df_ap2_bf	float	uJy	Uncertainty in i1_f_ap2_bf.

i1_f_ap1_3siglim	float	uJy	IRAC channel 1 (3.6 micron) three sigma upper limit on aperture flux density measured within an aperture of 3.8 arcsec and corrected to a total flux density. This column will have a non-null value only if there is no primary flux density and no bandfill flux density.
i1_f_ap2_3siglim	float	uJy	Same as i1_f_ap1_3siglim except within an aperture with diameter 5.8 arcsec.
i2_f_ap1	float	uJy	Same as i1_f_ap1 but for IRAC channel 2 (4.5 micron).
i2_df_ap1	float	uJy	Uncertainty in i2_f_ap1.
i2_f_ap2	float	uJy	Same as i2_f_ap2, but for IRAC channel 2 (4.5 micron).
i2_df_ap2	float	uJy	Uncertainty in i2_f_ap2.
i2_f_ap1_bf	float	uJy	Same as i1_f_ap1_bf but for IRAC channel 2 (4.5 micron).
i2_df_ap1_bf	float	uJy	Uncertainty in i2_f_ap1_bf.
i2_f_ap2_bf	float	uJy	Same as i1_f_ap2_bf, but for IRAC channel 2 (4.5 micron).
i2_df_ap2_bf	float	uJy	Uncertainty in i2_f_ap2_bf.
i2_f_ap1_3siglim	float	uJy	Same as i1_f_ap1_3siglim, but for IRAC channel 2 (4.5 micron).
i2_f_ap2_3siglim	float	uJy	Same as i1_f_ap2_3siglim, but for IRAC channel 2 (4.5 micron).
i3_f_ap1	float	uJy	Same as i1_f_ap1, but for IRAC channel 3 (5.8 micron).
i3_df_ap1	float	uJy	Uncertainty in i3_f_ap1.
i3_f_ap2	float	uJy	Same as i1_f_ap2, but for IRAC channel 3 (5.8 micron).
i3_df_ap2	float	uJy	Uncertainty in i3_f_ap2.
i3_f_ap1_bf	float	uJy	Same as i3_f_ap1_bf, but for IRAC channel 3 (5.8 micron).
i3_df_ap1_bf	float	uJy	Uncertainty in i3_f_ap1_bf.
i3_f_ap2_bf	float	uJy	Same as i1_f_ap2_bf, but for IRAC channel 3 (5.8 micron).
i3_df_ap2_bf	float	uJy	Uncertainty in i1_f_ap2_bf.
i3_f_ap1_3siglim	float	uJy	Same as i1_f_ap1_3siglim, but for IRAC channel 3 (5.8 micron).
i3_f_ap2_3siglim	float	uJy	Same as i1_f_ap2_3siglim, but for IRAC channel 3 (5.8 micron).
i4_f_ap1	float	uJy	Same as i1_f_ap1, but for IRAC channel 4 (8 micron).
i4_df_ap1	float	uJy	Uncertainty in i4_f_ap1.
i4_f_ap2	float	uJy	Same as i1_f_ap2, but for IRAC channel 4 (8 micron).
i4_df_ap2	float	uJy	Uncertainty in i4_f_ap2.
i4_f_ap1_bf	float	uJy	Same as i1_f_ap1_bf, but for IRAC channel 4 (8 micron).
i4_df_ap1_bf	float	uJy	Uncertainty in i4_f_ap1_bf.



i4_f_ap2_bf	float	uJy	Same as i1_f_ap2_bf, but for IRAC channel 4 (8 micron).
i4_df_ap2_bf	float	uJy	Uncertainty in i4_f_ap2_bf.
i4_f_ap1_3siglim	float	uJy	Same as i1_f_ap1_3siglim, but for IRAC channel 4 (8 micron).
i4_f_ap2_3siglim	float	uJy	Same as i1_f_ap2_3siglim, but for IRAC channel 4 (8 micron).
m1_f_psf	float	uJy	MIPS channel 1 (24 micron) PSF-fit flux density. This column will have a non-null value only if the detection is at a significance greater than 10 sigma.
m1_df_psf	float	uJy	Uncertainty in m1_f_psf. Formal uncertainty in the least-squares PSF fitting. This typically underestimates the true uncertainty. Users interested in more accurate uncertainties should use m1_f_psf / m1_snr.
m1_f_ap	float	uJy	MIPS channel 1 (24 micron) flux density measured with an aperture of diameter 14.7 arcsec. The flux densities have not had an aperture correction applied. For stellar point sources, multiply by 1.488. This column will be non-null only if the PSF flux density detection is greater than 10 sigma.
m1_df_ap	float	uJy	Uncertainty in m1_f_ap.
m1_f_psf_bf	float	none	MIPS channel 1 (24 micron) PSF-fit bandfill flux density. If a source is detected at >3 sigma within a 6 arcsec diameter aperture, a PSF fit is attempted. However, if the best fit centroid changes by more than 2 pixels (5 arcsec), only aperture flux densities at the original position are reported. If a source is not detected at >3 sigma in a 6 arcsec diameter aperture, only upper limits are reported.
m1_df_psf_bf	float	uJy	Uncertainty in m1_f_psf_bf. Formal uncertainty in the least-squares PSF fitting. This typically underestimates the true uncertainty. Users interested in more accurate uncertainties should use m1_f_psf / m1_snr.
m1_f_ap_bf	float	uJy	MIPS channel 1 (24 micron) bandfill flux density measured at the position ra, dec within an aperture of diameter 14.7 arcsec. The flux densities have not had an aperture correction applied. For stellar point sources, multiply by 1.488. This column will have a non-null value if the original detection was less significant than 10 sigma and the bandfill flux density is significant at a level greater than 3 sigma.
m1_df_ap_bf	float	uJy	Uncertainty in m1_f_ap_bf.
m1_f_psf_3siglim	float	uJy	MIPS channel 1 (24 micron) three-sigma upper limit on the PSF-fit flux density. This limit is calculated within a 6 arcsec diameter aperture.

m1_f_ap_3siglim	float	uJy	MIPS channel 1 (24 micron) three-sigma upper limit on the 14.7 arcsec diameter aperture flux density. No aperture correction has been applied.
i1_extfrac	float	none	The fraction of IRAC channel 1 (3.6 micron) pixels associated with the source that fall within the IRAC channel 1 extended source mask.
i2_extfrac	float	none	Same as i1_extfrac but for IRAC channel 2 (4.5 micron).
i3_extfrac	float	none	Same as i1_extfrac but for IRAC channel 3 (5.8 micron).
i4_extfrac	float	none	Same as i1_extfrac but for IRAC channel (8 micron).
m1_extfrac	float	none	Same as i1_extfrac but for MIPS channel 1 (24 micron).
i1_brtfrac	float	none	The fraction of IRAC channel 1 (3.6 micron) pixels associated with the source that fall within the IRAC channel 1 bright source mask.
i2_brtfrac	float	none	Same as i1_brtfrac but for IRAC channel 2 (4.5 micron).
i3_brtfrac	float	none	Same as i1_brtfrac but for IRAC channel 3 (5.8 micron).
i4_brtfrac	float	none	Same as i1_brtfrac but for IRAC channel 4 (8 micron).
m1_brtfrac	float	none	Same as i1_brtfrac but for MIPS channel 1 (24 micron).
i1_snr	float	none	Signal-to-noise ratio for i1_f_ap1.
i2_snr	float	none	Signal-to-noise ratio for i2_f_ap1.
i3_snr	float	none	Signal-to-noise ratio for i3_f_ap1.
i4_snr	float	none	Signal-to-noise ratio for i4_f_ap1.
m1_snr	float	none	Signal-to-noise ratio for m1_f_psf.
i1_x	float	pix	IRAC channel 1 (3.6 micron) x pixel position.
i1_y	float	pix	IRAC channel 1 (3.6 micron) y pixel position.
i2_x	float	pix	IRAC channel 2 (4.5 micron) x pixel position.
i2_y	float	pix	IRAC channel 2 (4.5 micron) y pixel position.
i3_x	float	pix	IRAC channel 3 (5.8 micron) x pixel position.
i3_y	float	pix	IRAC channel 3 (5.8 micron) y pixel position.
i4_x	float	pix	IRAC channel 4 (8 micron) x pixel position.
i4_y	float	pix	IRAC channel 4 (8 micron) y pixel position.
m1_x	float	pix	MIPS channel 1 (24 micron) x pixel position.
m1_y	float	pix	MIPS channel 1 (24 micron) y pixel position.
i1_ra	double	deg	Right Ascension (J2000) of the detection in IRAC channel 1 (3.6 micron).
i1_dec	double	deg	Declination (J2000) of the detection in IRAC channel 1 (3.6 micron).
i2_ra	double	deg	Right Ascension (J2000) of the detection in IRAC channel 2 (4.5 micron).
i2_dec	double	deg	Declination (J2000) of the detection in IRAC channel 2 (4.5 micron).

i3_ra	double	deg	Right Ascension (J2000) of the detection in IRAC channel 3 (5.8 micron).
i3_dec	double	deg	Declination (J2000) of the detection in IRAC channel 3 (5.8 micron).
i4_ra	double	deg	Right Ascension (J2000) of the detection in IRAC channel 4 (8 micron).
i4_dec	double	deg	Declination (J2000) of the detection in IRAC channel 3 (8 micron).
m1_ra	double	deg	Right Ascension (J2000) of the detection in MIPS channel 1 (24 micron).
m1_dec	double	deg	Declination (J2000) of the detection in MIPS channel 4 (8 micron).
i1_peakflux	float	uJy	IRAC channel 1 (3.6 micron) peak flux density.
i2_peakflux	float	uJy	IRAC channel 2 (4.5 micron) peak flux density.
i3_peakflux	float	uJy	IRAC channel 3 (5.8 micron) peak flux density.
i4_peakflux	float	uJy	IRAC channel 4 (8 micron) peak flux density.
i1_peakdist	float	arcsec	IRAC channel 1 (3.6 micron) distance from peak to centroid.
i2_peakdist	float	arcsec	IRAC channel 2 (4.5 micron) distance from peak to centroid.
i3_peakdist	float	arcsec	IRAC channel 3 (5.8 micron) distance from peak to centroid.
i4_peakdist	float	arcsec	IRAC channel 4 (8 micron) distance from peak to centroid.
i1_fwhm	float	arcsec	IRAC channel 1 (3.6 micron) full width at half maximum.
i2_fwhm	float	arcsec	IRAC channel 2 (4.5 micron) full width at half maximum.
i3_fwhm	float	arcsec	IRAC channel 3 (5.8 micron) full width at half maximum.
i4_fwhm	float	arcsec	IRAC channel 4 (8 micron) full width at half maximum.
m1_fwhm	float	arcsec	MIPS channel 1 (24 micron) full width at half maximum.
i1_a	float	arcsec	IRAC channel 1 (3.6 micron) semi-major axis.
i1_b	float	arcsec	IRAC channel 1 (3.6 micron) semi-minor axis.
i2_a	float	arcsec	IRAC channel 2 (4.5 micron) semi-major axis.
i2_b	float	arcsec	IRAC channel 2 (4.5 micron) semi-minor axis.
i3_a	float	arcsec	IRAC channel 3 (5.8 micron) semi-major axis.
i3_b	float	arcsec	IRAC channel 3 (5.8 micron) semi-minor axis.
i4_a	float	arcsec	IRAC channel 4 (8 micron) semi-major axis.
i4_b	float	arcsec	IRAC channel 4 (8 micron) semi-minor axis.
i1_seflags	int	none	IRAC channel 1 (3.6 micron) SExtractor flags.
i2_seflags	int	none	IRAC channel 2 (4.5 micron) SExtractor flags.
i3_seflags	int	none	IRAC channel 3 (5.8 micron) SExtractor flags.
i4_seflags	int	none	IRAC channel 4 (8 micron) SExtractor flags.
m1_dflag	int	none	MIPS channel 1 (24 micron) deblending flag.
m1_sflag	int	none	MIPS channel 1 (24 micron) APEX status flag.

m1_bad_pix	float	pix	MIPS channel 1 (24 micron) number of bad pixels in the PSF-fit region.
i1_gain	float	e/count	IRAC channel 1 (3.6 micron)
i2_gain	float	e/count	IRAC channel 2 (4.5 micron)
i3_gain	float	e/count	IRAC channel 3 (5.8 micron)
i4_gain	float	e/count	IRAC channel 4 (8 micron)
m1_gain	float	e/count	MIPS channel 1 (24 micron)
i1_meannoise	float	uJy	IRAC channel 1 (3.6 micron) mean 1-sigma noise at ra, dec.
i2_meannoise	float	uJy	IRAC channel 2 (4.5 micron) mean 1-sigma noise at ra, dec.
i3_meannoise	float	uJy	IRAC channel 3 (5.8 micron) mean 1-sigma noise at ra, dec.
i4_meannoise	float	uJy	IRAC channel 4 (8 micron) mean 1-sigma noise at ra, dec.
smid	long	none	<p>Super Mosaic ID number. AORs that are in the same Observation Class and are spatially contiguous are grouped into a Super Mosaic labeled with a single identification number: SMID. The first digit of the SMID indicates the Observation Class:</p> <p>2=zodiacal light 3=Galactic Plane 4=galactic 5=extended sources 6=extragalactic.</p> <p>If a Super Mosaic is divided into multiple Regions (see REGID) then its SMID will end in a 1. Otherwise, it will end in 0.</p>
regid	char	none	<p>Region ID name. If a Super Mosaic is larger than 0.25 square degrees, it is broken up into 300x300 square arcminute Regions, with each Region overlapping its neighboring Regions by 2.5 arcminute on all sides. The REGID begins with the SMID followed by a "-" followed by a Tile Number. For example, a REGID of 40002981-108 has an SMID of 40002981 and a Tile Number of 108. Two sets of Regions per position are created for IRAC data taken in High Dynamic Range (HDR) mode. The short frames are assigned a REGID with a "-short" suffix. An example is 40002981-108-short.</p>

irac_obstype	int	none	IRAC Observation Type: 2= Zodiacal Background Observation 3= Galactic Plane Observation 4= Galactic Object Observation 5= Extended Object 6= Extragalactic Observation.
mips_obstype	int	none	MIPS Observation Type, which is encoded in the same way as irac_obstype.
i1_coverage	float	images	IRAC channel 1 (3.6 micron) coverage.
i2_coverage	float	images	IRAC channel 2 (4.5 micron) coverage.
i3_coverage	float	images	IRAC channel 3 (5.8 micron) coverage.
i4_coverage	float	images	IRAC channel 4 (8 micron) coverage.
m1_coverage	float	images	MIPS channel 1 (24 micron) coverage.
twomass_key	int	none	2MASS Unique ID key
twomass_assoc	int	none	2MASS association flag. If this is set to 0, there is no 2MASS point source within a 1 arcsec radius. If there is a 2MASS association, this flag is set to 1.
twomass_ra	double	deg	Right Ascension (J2000) of the associated 2MASS point source, if any.
twomass_dec	double	deg	Declination (J2000) of the associated 2MASS point source, if any.
j	float	uJy	J-band flux density of the associated 2MASS point source, if any.
dj	float	uJy	Uncertainty in J.
h	float	uJy	H-band flux density of the associated 2MASS point source, if any.
dh	float	uJy	Uncertainty in H.
k	float	uJy	K-band flux density of the associated 2MASS point source, if any.
dk	float	uJy	Uncertainty in K.
wise_ra	double	deg	WISE J2000 right ascension with respect to the 2MASS PSC reference frame
wise_dec	double	deg	WISE J2000 declination with respect to the 2MASS PSC reference frame
wise1	double	uJy	WISE W1 flux density or 95% upper limit if the W1 flux measurement has SNR<2
dwise1	double	uJy	WISE W1 photometric measurement uncertainty in flux density units
wise2	double	uJy	WISE W2 flux density or 95% upper limit if the W1 flux measurement has SNR<2
dwise2	double	uJy	WISE W2 photometric measurement uncertainty in flux density units
wise3	double	uJy	WISE W3 flux density or 95% upper limit if the W1 flux measurement has SNR<2
dwise3	double	uJy	WISE W3 photometric measurement uncertainty in flux density units
wise4	double	uJy	WISE W4 flux density or 95% upper limit if the W1 flux measurement has SNR<2

dwise4	double	uJy	WISE W4 photometric measurement uncertainty in flux density units
wise_cc_flags	char	none	WISE contamination and confusion flag (see the definition of cc_flags in the WISE Explanatory Supplement)
wise_ext_flg	int	none	WISE extended source flag (see the definition of ext_flg in the WISE Explanatory Supplement)
wise_var_flg	char	none	WISE variability flag (see the definition of var_flg in the WISE Explanatory Supplement)
wise_ph_qual	char	none	WISE photometric quality flag (see the definition of ph_qual in the WISE Explanatory Supplement)
wise_det_bit	int	none	WISE bit-encoded integer indicating bands in which a source has a detection (see the definition of det_bit in the WISE Explanatory Supplement)
wise1rchi2	float	none	Reduced $\chi^2$ of the WISE W1 profile fit photometry measurement
wise1m	int	none	WISE W1 Integer frame coverage
wise1nm	int	none	WISE W1 Integer frame detection count
wise2rchi2	float	none	Reduced $\chi^2$ of the WISE W2 profile fit photometry measurement
wise2m	int	none	WISE W2 Integer frame coverage
wise2nm	int	none	WISE W2 Integer frame detection count
wise3rchi2	float	none	Reduced $\chi^2$ of the WISE W3 profile fit photometry measurement
wise3m	int	none	WISE W3 Integer frame coverage
wise3nm	int	none	WISE W3 Integer frame detection count
wise4rchi2	float	none	Reduced $\chi^2$ of the WISE W4 profile fit photometry measurement
wise4m	int	none	WISE W4 Integer frame coverage
wise4nm	int	none	WISE W4 Integer frame detection count

## Chapter 5. Additional Tables

### 5.1 Coverage Tables

There are two coverage map tables, one for the 4 IRAC channels and one for MIPS channel 1 (24 microns). Users can search a given ra and dec to find out if there is a Super Mosaic that covers the search location. The IRAC table is binned on a scale of  $4.6 \times 4.6$  arcsec<sup>2</sup> and the MIPS table is binned on a scale of  $9 \times 9$  arcsec<sup>2</sup>.

**Table 5.1 Contents of IRAC Coverage Table.**

Column Name	Units	Description
smid		Super Mosaic ID number
regid		Region ID name
ra	degrees	Right Ascension (J2000)
dec	degrees	Declination (J2000)
duplicate		if nonzero, area is duplicated in mosaics.
crowded		If nonzero, area is crowded.
i1_coverage	images	Number of images in IRAC Ch1.
i1_uncertainty	uJy	Uncertainty in IRAC Ch1.
i1_brightmask		If nonzero, area is affected by bright source in IRAC Ch1.
i1_extendedmask		If nonzero, area is affected by extended source in IRAC Ch1.
i1_rejectedsources		Number of rejected sources in IRAC Ch1.
i2_coverage	images	Number of images in IRAC Ch2.
i2_uncertainty	uJy	Uncertainty in IRAC Ch2.
i2_brightmask		If nonzero, area is affected by bright source in IRAC Ch2.
i2_extendedmask		If nonzero, area is affected by extended source in IRAC Ch2.
i2_rejectedsources		Number of rejected sources in IRAC Ch2.
i3_coverage	images	Number of images in IRAC Ch3.
i3_uncertainty	uJy	Uncertainty in IRAC Ch3.
i3_brightmask		If nonzero, area is affected by bright source in IRAC Ch3.
i3_extendedmask		If nonzero, area is affected by extended source in IRAC Ch3.
i3_rejectedsources		Number of rejected sources in IRAC Ch3.
i4_coverage	images	Number of images in IRAC Ch4.
i4_uncertainty	uJy	Uncertainty in IRAC Ch4.
i4_brightmask		If nonzero, area is affected by bright source in IRAC Ch4.
i4_extendedmask		If nonzero, area is affected by extended source in IRAC Ch4.

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i4_rejectedsources		Number of rejected sources in IRAC Ch4.
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**Table 5.2 Contents of MIPS Coverage Table.**

Column Name	Units	Description
smid		Super Mosaic ID Number
regid		Region ID Name
ra	degrees	Right Ascension (J2000)
dec	degrees	Declination (J2000)
duplicate		If nonzero, area is duplicated in mosaics.
coverage	images	Number of images in MIPS Ch1.
uncertainty	uJy	One sigma points source depth of images in MIPS Ch1
brightmask		If nonzero, area is affected by bright source in MIPS Ch1.
extendedmask		If nonzero, area is affected by extended source in MIPS Ch1.
nrejectedsources		Number of rejected sources in MIPS Ch1.

## 5.2 Traceback Table

The Traceback Table contains all the information needed to reproduce a given Super Mosaic.

**Table 5.3 Content of Traceback Table.**

Column Name	Description
smid	Super Mosaic ID number
regid	Region ID
instrument	Instrument
channel	Instrument Channel
dce	DCE Number
aor	Astronomical Observation Request Number
pid	Program ID
mjd	Modified Julian Date of observations.
exptime	Exposure Time
ra	Right Ascension (J2000)
dec	Declination (J2000)
pa	Position angle
l	Galactic Longitude
b	Galactic Latitude
ism	Expected Interstellar Medium Background
zody	Expected Zodiacal background



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## Chapter 6. Change Log

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### Version 3.0:

1. Release of galactic fields previously held back.
2. WISE photometry now from AllWISE release.
3. Masking adjustments in all bands.
4. Error in MIPS channel 1 Aperture bandfill error and 3siglim fixed.

### Version 2.0:

1. Some MIPS channel 1 mosaics had obvious processing issues. All mosaics were visually inspected and badly-processed mosaics were re-created.

### Preliminary Release version 1.1 (PR1.1):

1. \*\_Fluxtype 4 has been added to denote sources that are bright and detected in multiple bands, but fail to meet the size criteria. These sources are real, but will have inaccurate flux densities, so no flux densities are reported.
2. Flagging parameters have been optimized to improve completeness.
3. The algorithm to detect extended backgrounds was changed. The new algorithm divides the image into a grid and calculates the mean of the lower-quartile of pixels in each grid square. A surface is then tessellated over these lower-quartile values, and SExtractor is used to segment regions of elevated emission into a mask.
4. The bright source mask for MIPS is now derived from the WISE catalog
5. A latent mask was added near very bright MIPS sources for scan map mode data.
6. WISE sources within 3 arcsec of a source list source are now reported. WISE detections add to the NBands value, along with any 2MASS association.
7. The SExtractor background subtraction and detection settings used for the IRAC photometry have been optimized.
8. The APEX background settings and aperture settings used for MIPS photometry have been optimized.
9. The MIPS PSF flux densities have been corrected for the PSF normalization used in APEX to better reflect accurate total flux densities.
10. The MIPS aperture flux densities have been corrected to total flux densities.

11. The MIPS bandfill fluxes are now calculated using a two pass method to avoid over-reporting the flux densities of faint sources next to bright sources. If a source is not detected at  $>3$  sigma in a 6 arcsec diameter aperture, only upper limits are reported. If a source is detected at  $>3$  sigma, a PSF fit is attempted. However, if the best fit centroid changes by more than 2 pixels (5 arcsec) only aperture flux densities at the original position are reported.
12. MIPS PSF flux density limits have been replaced by 6 arcsec diameter aperture limits to avoid nearby bright sources from biasing the limits.
13. Only the central bright source flux is now reported within MIPS bright source masks. This avoids false detections of artifacts on the airy ring.
14. Sources detected only in MIPS or MIPS+2MASS are no longer reported to reduce the artifact rate.
15. Ancillary structural and photometric information such as SNR, FWHM, mask bits, area, etc. are now reported along with bandfill flux densities. For IRAC, these values are calculated using a similar, but different, algorithm than SExtractor uses for the main detections, so they may not be exactly comparable. The MIPS structural parameters are calculated identically whether main flux densities or bandfill flux densities are reported.
16. The gain used to calculate photometric noise now reflects the mean exposure time used in each mosaic as well as the coverage.
17. Galactic Coordinates have been added to the Source List.

## Appendix A. Acronyms

2MASS	The Two Micron All Sky Survey – J(1.25 microns), H (1.65 microns), Ks (2.17 microns)
AllWISE	Combines data from WISE cryogenic and NEOWISE post-cryogenic surveys
AOR	Astronomical Observation Request
BCD	Basic Calibrated Data – Spitzer term for the calibrated image most users begin with (prior to any mosaicing).
EIP	Enhanced Imaging Product
IER	Instrument Engineering Request – like an AOR, but for specific engineering tasks not able to be accomplished using an AOR.
IRAC	InfraRed Array Camera
IRSA	InfraRed Science Archive
MIPS	Multiband Imaging Photometer for Spitzer
PID	Program ID
SEIP	Spitzer Enhanced Imaging Products
SHA	Spitzer Heritage Archive
SSC	Spitzer Science Center
SL	The Spitzer Source List
WISE	Wide-Field Infrared Survey Explorer

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